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California, Oregon, and Washington Archaeological Resource Study

Volume I: Management Summary

Project Editors

Robert L. Gearhart II
Clell L. Bond
Steven D. Hoyt

Volume I Authors

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Kim Marcus
Andrew York

Prepared under MMS Contract

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by

Espey, Huston & Associates, Inc.

P.O. Box 519

Austin, Texas 78767

Subcontractor:

Dames & Moore

San Diego, California

Published by

U.S. Department of the Interior

Minerals Management Service

Pacific OCS Region

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This report has been reviewed by the Minerals Management Service and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Service, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.



ABSTRACT

In May 1989, the Pacific OCS Region of MMS contracted with Espey, Huston & Associates, Inc. (EH&A) of Austin, Texas to conduct a study of the OCS between Morro Bay, California and the Canadian Border. Overviews are presented for late Pleistocene/Holocene geology of the OCS, for prehistory of the coastal zone, and for maritime history of the study area. Models are formulated to predict the areas in which prehistoric and historic archaeological sites are likely to be preserved on the OCS. Variables considered by these models include late Pleistocene and Holocene geology of the OCS, known archaeological site distributions, prehistoric settlement patterns, vessel traffic patterns, and the distribution of significant hazardous weather conditions. Holocene geology, known site distributions, and archaeological site predictive zones resulting from this project have been mapped at a scale of 1:250,000 and are bound as an atlas for inhouse use by MMS. Smaller scale copies of these maps, lacking specific locational information for archaeological sites, have been produced for public distribution. The results of this study will be used in evaluating exploration, development and transportation plans for mineral development activities on the OCS and in determining remote-sensing survey requirements that will apply to specific areas of the OCS.



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This study was coordinated by Mr. Robert Gearhart, EH&A Senior Staff archaeologist, with the assistance of Mr. Clell Bond, EH&A Vice President and manager of EH&A's cultural resources group. Together, Mr. Gearhart and Mr. Bond were responsible for the organization, editing and final content of these six volumes. Editorial assistance was contributed by Mr. Steven Hoyt, EH&A staff archaeologist. Principal Investigators for this study were: Mr. Robert Gearhart (responsible for historic and marine archaeology); Dr. Pandora Snethkamp (D&M archaeologist responsible for California prehistory); Dr. Gary Wessen (D&M archaeologist responsible for Washington and Oregon prehistory); and Mr. Kim Marcus (D&M geologist responsible for geology). Contributing authors, in alphabetical order, include: Mr. Jim Anderson (D&M geologist); Dr. James Cleland (D&M archaeologist); Mr. Robert Gearhart; Mr. Steven Hoyt; Mr. Kim Marcus; Mr. John Neville (EH&A archaeologist); Dr. Pandora Snethkamp; Dr. Gary Wessen; Dr. Jerry Wilson (D&M geologist); and Mr. Andrew York (D&M archaeologist). All work performed by D&M for this study was conducted under the supervision of Dr. James Cleland, a senior member of D&M's archaeological staff.

This report was critically reviewed by a Quality Review Board consisting of experts in geology, Pacific coast prehistory and marine archaeology. Our thanks to Dr. Curt Peterson (marine geologist and Assistant Professor with Portland State University), Dr. Lee Lyman (Northwest Coast prehistorian and faculty with the University of Missouri, Columbia), and Mr. J. Barto Arnold III (marine archaeologist with the State of Texas) for serving on the review board.

A special thank you is due the staff of Minerals Management Service, including especially Dr. Gary Brewer, Mr. Alex Watt and Ms. Melanie Stright, for their sponsorship and technical advice.

EXECUTIVE SUMMARY

In May 1989, the Pacific OCS Region of MMS contracted with Espey, Huston & Associates, Inc. (EH&A) of Austin, Texas to conduct a study of the OCS between Morro Bay, California, and the Canadian border. This six-volume report is the last in a series of similar baseline reports which evaluate the archaeological potential of the OCS. The results of this study will be used in evaluating exploration, development and transportation plans for mineral development activities. The identification of areas on the OCS in which prehistoric and historic archaeological sites are likely to be preserved will assist MMS in determining remote-sensing survey requirements that will apply to specific portions of the study area. Several disciplines contributed to this study including: geology, prehistory and maritime history. The techniques of archaeology apply to both the prehistoric and historic aspects of this study.

Late Pleistocene and Holocene geology of the continental shelf were integral to this study. The primary geologic objectives were to characterize the Pacific OCS paleogeography when sea level was at its most recent low stand approximately 18,000 B.P., and to postulate the effects of subsequent sea level rise on landforms likely to contain prehistoric habitation sites.

Geologic data pertaining to the Pleistocene/Holocene transition is sparse for the study area, especially regarding Holocene sediment cover. The Pacific OCS is significantly narrower than the world average and, over most of its area, has a gently sloping featureless surface. At the end of the Pleistocene, the OCS (then a coastal plain) was likewise characterized by a flat level terrain. Prior to about 10,000 B.P., coastal streams would have flowed along low-gradient meander belts and probably would have carried high sediment loads. The combination of a low-gradient coastal plain and an abundance of sand suggests the possibility that much of the northern study area coast was characterized by an energy-dissipating barrier island system prior to 10,000 B.P. The Texas Gulf coast may be an appropriate modern analog. The OCS off of California prior to 10,000 B.P. may have resembled the coast of southern Florida (except for the absence of karst topography off of California). By 10,000 B.P., the coast had migrated significantly eastward and was approaching the position of the modern coastline where the slope of the OCS is steeper. Wave energy would have been more severe and erosion more active as the wave ramp became steeper. The coastline has changed relatively little in the past 7,500 years. By 3,000 B.P., sea level approximated that of today.

The most likely locations in the study area for the occurrence and preservation of submerged prehistoric sites are submerged estuaries, paleoembayments, lagoons, submerged river valley systems, and on the lee side of islands and headlands. Sites located along unprotected coastlines and in areas now lacking Holocene sediment cover are least likely to have survived inundation. Sites that were buried by sedimentation prior to inundation have the greatest chance for preservation in all environments. No submerged sites have been located in the study area; however, the potential is good for their occurrence and preservation under the proper circumstances.

Submerged landforms that are most likely to contain preserved prehistoric sites have been mapped in Volume V. The approximate location of numerous submerged meander belts were inferred from the positions of modern river mouths and submarine canyons on the continental slope. These meander belts are also the most likely locations for drowned estuaries. Drowned islands and headlands were identified from modern bathymetric charts.

Approximately 3,850 shipwrecks have been historically documented for the study area. It is estimated that between 80 and 90 percent of these occurred in less than 10 m of water, in what we have called the nearshore zone. Harbor entrances, inner harbor waters, and the

nearshore zone are the most likely areas for the occurrence of shipwrecks. Mineral development activities associated with pipeline and port facility construction could affect wrecks in the nearshore zone. The balance of documented wrecks occurred offshore. Offshore wrecks are most likely to be impacted by OCS mineral exploration and development. The most likely locations for offshore wrecks are harbor approaches and high-traffic sealanes.

A high correlation exists between severe weather and the occurrence of shipwrecks. Over 50 percent of all marine casualties in the study area were weather related. The most significant weather conditions affecting vessel losses are high winds/heavy seas and fog, thus average wind speed and the frequency of low visibility due to fog were incorporated into the historic site predictive model.

Marine CRM requirements for compliance with Section 106 of the National Historic Preservation Act are presently lagging far behind the requirements for archaeology in terrestrial settings. This discrepancy seems to be based upon misperceptions regarding both the benefits and the relative cost of marine archaeology by comparison with terrestrial archaeology. Survey requirements, especially line-spacing, should be more stringent. A heavy emphasis should be placed on regional mapping of marine survey results so future survey results can be analyzed in the context of surrounding areas. Such a program would improve the quality both of data interpretations and of survey reports and would allow refinement of the archaeological site predictive models formulated for this study. Incorporation of such ideas into MMS' archaeological requirements could greatly increase the level of our knowledge regarding archaeological sites on the OCS while resulting in a significant cost savings to industry.

1.0 INTRODUCTION

In 1974 a federal archaeology program was begun for the submerged lands of the outer continental shelf (OCS) bordering the United States. This program was originated under the auspices of the U.S. Bureau of Land Management (BLM) and the U.S. Geological Survey (USGS), and was the child of three legislative acts: the National Historic Preservation Act, the National Environmental Policy Act, and the OCS Lands Act. As a result of these laws, BLM was required to consider the potential effect of OCS mineral exploration and development on submerged archaeological resources. In 1982, the offshore and royalty management functions of BLM and USGS were combined and restructured to form the Minerals Management Service (MMS). Since then, MMS has been the agency responsible for protecting archaeological resources on the OCS from the effects of Federally permitted mineral activities.

Since the inception of the federal OCS archaeology program, a number of regional baseline studies, similar to this project, have been sponsored by MMS. The purpose of these studies has been "to evaluate the potential for archaeological resources to occur on the submerged, federally controlled lands...[and] to establish a rational framework on which to base management decisions concerning activities [on the OCS] and their potential effect on archaeological resources" (MMS Request for Proposal No. 3439). All mineral exploration and development (including, for example, oil and gas, heavy metals, sand, shell, and sulphur) on the OCS fall into the category of MMS-permitted actions.

The OCS from Morro Bay, California, northward to the Canadian border is the final segment of the U.S. coastline of the contiguous 48 states to be addressed by a comprehensive study of this type. The first study of this series was conducted in the Gulf of Mexico for the New Orleans OCS office of MMS (then BLM) by Coastal Environments, Inc. (Gagliano 1977). Since that time, studies have been conducted by Harvard University for the Atlantic region from the Bay of Fundy to Cape Hatteras (Institute for Conservation Archaeology 1979), by Science Applications, Inc. (1981) for the Atlantic coast from Cape Hatteras to Key West, Florida, for the Alaskan OCS by the University of Alaska in Fairbanks (Dixon et al. 1986), and for the Pacific coast OCS, south of Morro Bay, California, by Science Applications, Inc. (1977) and PS Associates (Pierson et al. 1987). This six-volume study is the last in a series of MMS regional baseline studies summarizing the archaeological potential of the OCS.

In May 1989, the Pacific OCS Region of MMS in Los Angeles contracted with Espey, Huston & Associates, Inc. (EH&A) of Austin, Texas, to conduct a baseline study of submerged archaeological resources for the Pacific OCS region between Morro Bay, California, and the Canadian border. EH&A subcontracted portions of this effort pertaining to geology and prehistory to the firm of Dames & Moore (D&M) of San Diego. The results of this study have been compiled under the supervision of EH&A into a six-volume compendium.

The results of this study will be used in Environmental Impact Statements, Secretarial Issue Documents, final tract selections, and in developing lease stipulations regarding archaeological resources. The identification of those portions of the region having a high probability for the occurrence and preservation of prehistoric resources and the identification of shipwreck locations will assist the MMS in determining which areas will require remote-sensing surveys prior to mineral development (MMS Request for Proposal No. 3439). Results will also be used in evaluating exploration, development and transportation plans for mineral development activities.

1.1 Study Area Boundaries

The geographic area encompassed by this study (Figure I-1) includes the Pacific coast OCS bordering central and northern California, Oregon, and Washington and includes the inner continental shelf (within the 3-mile limit), estuaries, and a narrow strip of land referred to as the coastal zone. The coastal zone is defined for the purpose of this study as beginning at the mean high water level and extending landward a minimum distance of 0.5 kilometer (km). In areas where high cliffs back a narrow sandy or rocky beach, the coastal zone is limited to the minimum 0.5-km distance. In areas where the coastline widens to form a broad beach with adjoining sand dunes, salt marshes, lagoons or estuaries, the coastal zone encompasses such features. Many rivers are tidally influenced for miles upstream of the bays at their mouths. Technically these areas might be considered as estuaries; however, in such cases, the study area is limited to the geographic extent of an obvious bay formed at the mouth of a river. An artificial eastern boundary for the study area was established in the northern arm of San Francisco Bay at the Vallejo-Crockette Bridge. Puget Sound and the Strait of Juan de Fuca are excluded from the study area.

1.2 Content and Organization of Report Volumes

This report is comprised of six separately bound volumes: I - Management Summary; II - Geology; III - Prehistory; IV - History; V - Small-Scale Maps; and VI - Appendices. The effort in conducting this study and preparing these six volumes was divided between the two firms along the following lines. EH&A, as the prime contractor, provided expertise in marine archaeology, remote-sensing and computer-assisted design (CAD) mapping, and was responsible for the final content and editorial style of each volume. D&M provided expertise in the fields of geology and prehistoric archaeology and authored volumes II and III pertaining, respectively, to these disciplines. This report was compiled and edited by EH&A.

An effort has been made to organize the contents of each volume in as logical a manner as possible. The primary organizational theme to these volumes is by discipline. Volume I, Management Summary, is primarily intended to summarize and to discuss topics which pertain to the overriding subject of this study. Volumes II, III, and IV are the foundation of this study. These volumes contain detailed discussions of the three disciplines that are central to this project: geology, prehistory and history, respectively. Though the science of archaeology is integral to both the prehistoric and the historic record in this case, the text has been separated along the lines stated above, rather than discussing geology in one volume and archaeology, both prehistoric and historic, in another volume. This approach is the most logical for the purposes of the current study.

Volume II presents a general summary of the study area's environment and geologic history. For ease of discussion in Volume II, the study area has been separated into four subregions based on similarities of the geologic history and currently active geologic processes. The separate subregions consist of Cape Flattery to Heceta Head; Heceta Head to Cape Mendocino; Cape Mendocino to Morro Bay; and the San Francisco Bay area. Each subregion discussion includes a general characterization of the area followed by descriptions of the coastal physiography, tectonic history and setting, shelf physiography, geology, oceanographic setting, late Pleistocene/Holocene stratigraphy, sea level fluctuations, and Holocene sediment isopach maps, as well as a section on the specific features judged to have the greatest potential for prehistoric occupation.

Volume III, the Prehistory volume, presents a summary of existing archaeological and ethnographic data for the coastal zone. This discussion in Volume III is organized by

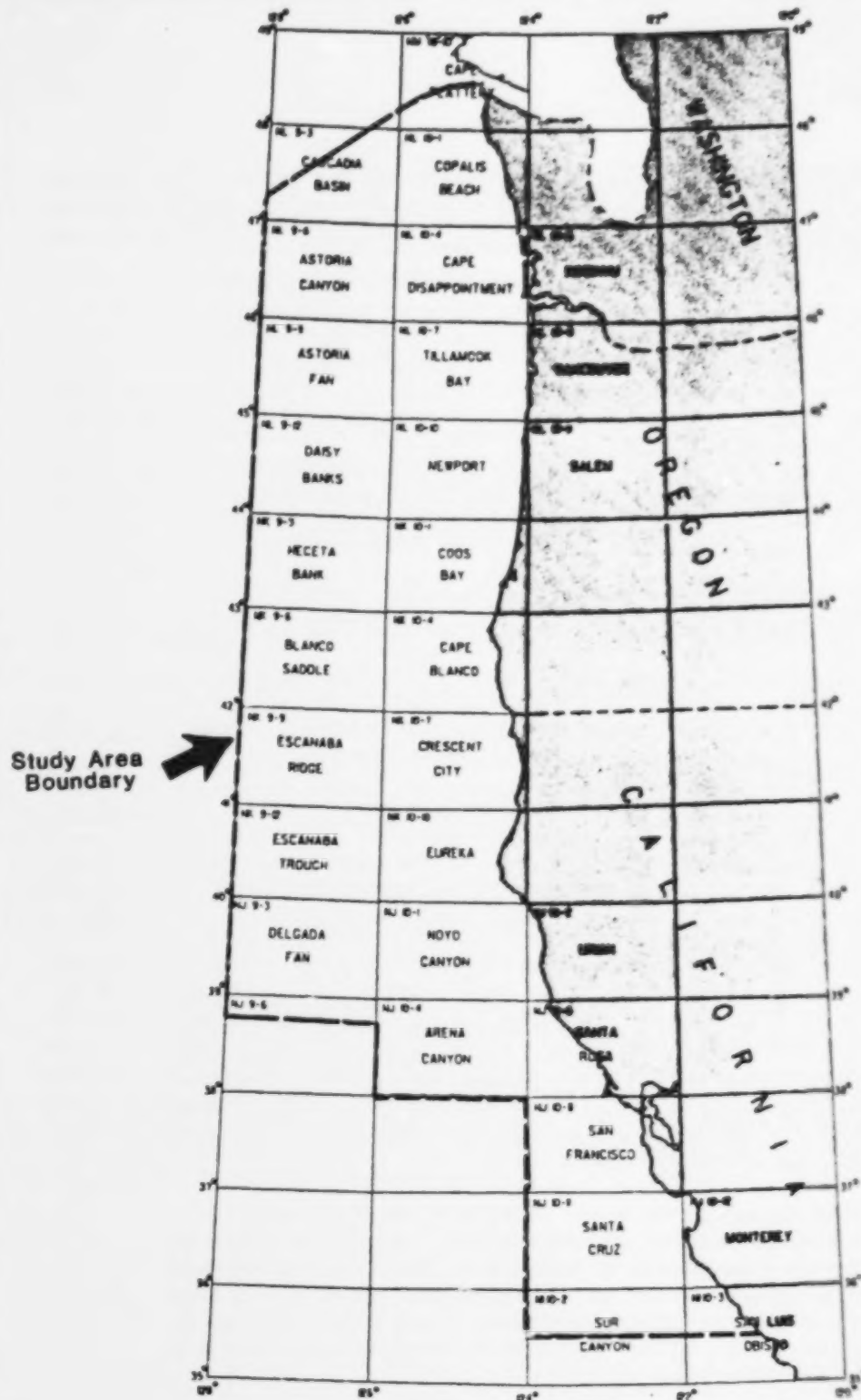


Figure I-1. Study Area for the California, Oregon and Washington Archaeological Resource Study.

geographic/cultural subregions, including: Central California, San Francisco Bay, Northern California, Oregon, the Columbia River, and Washington. Previous archaeological investigations, culture history, ethnographic cultures, and settlement/subsistence models are discussed separately for each of these subregions.

Volume IV summarizes the maritime history of the study area, discusses the results of the historic literature search, and describes the historic site predictive model. Historic topics are organized chronologically. Volume IV includes a summary of previous marine archaeological investigations conducted in and near the study area. Aspects of the physical environment that would affect marine navigation are discussed in detail in connection with this historic site predictive model. Some overlap occurs between volumes II and IV regarding the physical oceanography and meteorology of the study area.

Volume V is an atlas, illustrating late Pleistocene/Holocene geology, known archaeological site distributions, and predictive zones for prehistoric and historic archaeological sites. A second, more-detailed set of maps was prepared at a scale of 1:250,000 for in-house use by MMS. The maps illustrated in Volume V do not show specific archaeological site identifications. Nevertheless, these maps should give the reader a general feeling for the density and distribution of archaeological and geological data in the study area, as well as a necessary point of reference for details and interpretations which are discussed in the text of volumes I through IV.

There are a total of 31 map units in the study area. Seven types of data overlays were produced for each map unit, with the exception that geologic and prehistoric maps were not required for those units located beyond the western edge of the continental shelf. A total of 138 unique large-scale (1:250,000) maps have been produced for this project. All but the geologic data source maps have been included in the large-scale atlas with detailed base map and site-specific information, for use internally by MMS. The small-scale map sheets (Volume V) contain less-detailed information and are for public distribution. Volume V contains the geologic data source maps for each map unit. The types of data overlays produced for this project are briefly summarized below. More detailed information regarding the contents of each type of map, the sources of this information, and the interpretation of these maps can be found in the volumes pertaining to each discipline.

Holocene sediment isopach maps: These maps illustrate the thickness of sediments deposited on the continental shelf during the Holocene period. The thickness data comes from a variety of sources including seismic surveys and bottom coring studies. Relatively little geophysical work has been done in the study area in comparison to regions where significant offshore oil and gas development has occurred, thus these maps are unavoidably simplistic.

Geologic data source maps: These maps are the equivalent of a bibliography, indicating the institutional source and literature citation for the data represented on the isopach maps. Again, the limited amount of geophysical work that has been done in the area is reflected by these maps. They are illustrated in Volume V only. MMS agreed that the sparse nature of the data represented did not warrant the production of large-scale versions.

Paleo-landform maps: This set of maps shows major topographic features, such as river systems, of the late Wisconsin (pre-inundation) land surface, as well as Holocene sea-level stands and major geologic faults that might have contributed to rapid inundation of prehistoric sites along some sections of the coast.

Prehistoric site location maps: The known locations of prehistoric sites in the coastal zone and on the continental shelf are illustrated on this set of maps.

Prehistoric site predictive zone maps: The graphic results of the predictive model for submerged prehistoric site locations is illustrated on this set of maps. This model is based upon our knowledge of human settlement patterns, continental shelf geology and sea-level rise for the period of probable human occupation in the New World.

Historic site location maps: This set of maps illustrates the known locations of shipwrecks and other types of submerged historic sites, including downed aircraft. The locations indicated on these maps are not limited to archaeological sites. Locations of vessel strandings and sinkings in which the vessels were later removed from the scene are also indicated, as the latter information contributes to our understanding of high probability areas for vessel loss.

Historic site predictive zone maps: These maps illustrate the zones of high versus low probability for the occurrence of historic sites, primarily shipwrecks, on the continental shelf. They represent a graphic depiction of the historic site location predictive model.

As a general rule, if any technical topic pertains specifically to one of the three main disciplines around which this study is organized (geology, prehistory and history), then that topic has been discussed in the appropriate volume for that discipline. The exception to this rule concerns discussion of methods and research orientation. These have been placed in Volume I in an effort both to avoid redundancy and to limit the content of volumes II through IV to syntheses and discussion of the predictive models. Bibliographic references cited in the text of each volume are included in the final section of the volume in which they are cited. A more comprehensive bibliography including all references cited in the text, as well as many additional references, is included in Volume VI as Appendix B. All appendices are bound separately from the remainder of the report as Volume VI.

2.0 RESEARCH DESIGN

The primary objectives of this project are to assess the archaeological potential of the study area for containing intact cultural deposits from both the prehistoric and historic periods and to determine the most likely areas in which such cultural deposits would be expected to occur. In order to accomplish these objectives, MMS has spelled out several specific requirements for this study:

- 1) Develop a comprehensive archaeological database for the study area;
- 2) Map the study area showing locations of known prehistoric sites on the OCS and in the coastal zone;
- 3) Map the locations of known historic sites on the OCS;
- 4) Map the Holocene marine geology of the study area showing Holocene sediment isopachs and surface geology of the pre-Holocene (pre-inundation) continental shelf; and
- 5) Determine and map the most probable locations in the study area for the presence of submerged, intact prehistoric and historic archaeological sites.

The work effort required to complete this project has been divided into four tasks: geology, prehistory, history and mapping. A brief description of the each task is provided below. Geological research entailed acquisition, review and synthesis of pertinent geologic literature and geophysical survey data. Additionally, the geologists consulted extensively with the prehistorians regarding potential environments on the continental shelf that would likely contain intact prehistoric sites. The tasks of assembling and synthesizing the required information for prehistory and history were each broken down into four subtasks: 1) literature review and data acquisition; 2) computerization of the database; 3) synthesis of the literature and data; and 4) formulation of a predictive model. Separate archaeological databases were compiled for prehistoric and historic sites as part of MMS's Archaeological and Shipwreck Information System (ASIS). The ASIS database, in conjunction with the site location and predictive zone maps, will assist MMS in the management of submerged historic and prehistoric resources on the OCS. Extensive mapping was required of all three disciplines involved in this project. Compilation of map data provided by each discipline was done by EH&A's computer cartographic staff in Austin.

2.1 Geology

The initial phase of this investigation included the identification and preliminary assessment of pertinent data sources, including both literature and professional geologists. Geologic information was obtained from published and in-press literature and from unpublished sources including discussions with active researchers and retired scientists regarding available geologic data sources and likely locations of favorable geologic conditions for the preservation of prehistoric sites on the shelf. From these initial data sources the amount of information was expanded. Extensive library searches were conducted, including libraries at the University of

Washington, University of Oregon, Oregon State University, Portland State University, Stanford University, and the U.S. Geological Survey library in the Menlo Park, California. Information garnered directly from individuals or through printed references was immeasurably helpful in completing this project. Over 600 references were used and more than 50 individuals were consulted in the process of gathering information on the Holocene geology of the study area. The individuals and agencies consulted for geologic information are cited in Appendix A, in Volume VI. A comprehensive list of geologic literature consulted is included as one section of Appendix B.

Far less geologic data was available for the study area than was the case for earlier similar studies conducted for MMS on the southern California OCS. Comparatively little shallow seismic research has been conducted in the present study area due to the absence of proven economic oil and gas fields. Much of the seismic data from the study area was collected using low frequency, deep-penetration seismic profilers. As a result, knowledge of Holocene geology in the study area is relatively limited.

2.2 Prehistory

In order to assess the potential for prehistoric resources on the OCS, a thorough records search and literature review pertaining to the prehistory of the coastal zone was undertaken. The literature search involved the gathering of reference material for the coastal area and the generation of an extensive bibliography for prehistoric coastal archaeology (Appendix B).

Archaeological record searches were conducted at the following locations: California Archaeological Inventory, South Coastal Information Center, University of California, Santa Barbara; Northwest Information Center, Sonoma State University; Oregon State Historic Preservation Office; and the Washington Office of Archaeology and Historic Preservation. The record search included all sites within the coastal zone. In California the record search utilized digital transfer of computerized site information from the state's archaeological site database. A program was written to convert the state archaeological database into MMS' dBase III+ file structure for this project. In Oregon and Washington, the data transfer was done manually, requiring that site locations be plotted on 1:250,000 scale project maps for later digitization and that archaeological site records be photocopied and manually entered into the MMS prehistoric site database.

During the course of these investigations, many individuals and organizations, having interest in or knowledge of coastal archaeology, were contacted. Contacts included professional archaeologists with research interests along the coast, as well as state and federal agencies with responsibilities for managing coastal resources. The latter included the Bureau of Land Management (BLM), the U.S. Army Corps of Engineers (USCE), the National Park Service (NPS), and California State Parks. Also contacted were the State Historic Preservation Officers for California, Oregon, and Washington. A complete contact list is included in Appendix A.

Data on known prehistoric site distributions was collected for the coastal zone, and archaeological predictive models purporting to explain these distributions were reviewed and assessed. Existing theories on early human settlement of the coast and adjacent areas were evaluated to determine what sorts of predictions can be made regarding the distribution of prehistoric sites on the OCS.

2.3 Maritime History

A vast body of literature exists concerning the maritime history and archaeology of the study region. It was the first goal of this task to identify pertinent sources of information,

published and unpublished, and to compile a thorough bibliography of these sources. References were gathered from several origins. Published references were identified from existing bibliographies and from extensive searches of library card catalogs. Some unpublished material was also discovered in this manner, as well as from various archival finding aides. A bibliography resulting from the literature search for published sources and unpublished manuscript material, with references separated by discipline, is included in Appendix B.

From the list of maritime sources presented Appendix E, a subset was selected consisting of those which together would represent the best balance between a succinct and comprehensive treatment of the subject. This subset represents the sources relied upon most heavily when researching the text of Volume IV. A bibliography of references specifically pertinent to documenting vessel losses was compiled in connection with the historic site database (Appendix E).

The majority of unpublished information was identified through conversations with countless knowledgeable individuals. A list of individuals contacted in connection with maritime aspects of this project is provided in Appendix A. No doubt, there are some individuals whose names, inadvertently, have been omitted from this list. For this we offer our humble apologies.

Other unpublished sources were identified by means of two requests for information sent out through the mail. The first request was mailed to historical societies, maritime museums, and institutions known to have major collections of manuscripts. The level of response was very favorable. The results are included as Appendix D. The second request for information was designed specifically to locate collections of historic newspapers and to determine which of these collections have been indexed. The results of this mailout have been summarized as Appendix F.

A computerized listing of historic sites known to be present within the study region was developed as one aspect of this project. Since this database consists almost exclusively of shipwrecks, it may be alternately referred to as the shipwreck database throughout the remainder of this report. The shipwreck database is one of the two databases developed for this project as part of MMS' ASIS database. The format for the shipwreck database was established by MMS in conjunction with earlier OCS archaeological studies.

Locational information contained in the shipwreck database is confidential under Section 304 of the National Historic Preservation Act. The database is maintained by MMS along with maps showing wreck locations keyed to the database listings. The Historic Site Location Maps illustrated in Volume V are non-specific as to the identity of shipwrecks. This information is available upon request to qualified researchers. Requests should be directed to:

Chief, Environmental Studies Section
Minerals Management Service
Pacific OCS Region
770 Paseo Camarillo
Camarillo, California 93010

2.4 Mapping

A major element of the work effort for this study was involved in the production of a series of 1:250,000 scale maps to be used by MMS when assessing OCS cultural resource requirements for individual lease blocks. Seven distinct types of map have been produced (described below). Because some of these maps contain site-specific locational information, they are not available for general distribution to the public; however, simplified, small-scale versions of

each map have also been produced, in an 8.5-inch X 11-inch format, for public distribution. The latter maps have been bound together to form Volume V of this report.

Each map covers an area measuring one degree in latitude by two degrees in longitude, corresponding to the coverage of the 1-degree by 2-degree subdivisions on the OCS Protraction Diagram (see map key at the beginning of Volume V). The area of coverage for coastal map units also corresponds to that of the U.S. Geological Survey (USGS) 1:250,000-scale topographic series maps by the same names.

2.4.1 *Base Map Preparation*

Base information for the large-scale map sheets was acquired directly from governmental mapping agencies, including USGS in Denver, the National Ocean Service (NOS) in Rockville, Maryland, MMS in Los Angeles, and the Naval Oceanographic Office of the Stennis Space Center in Mississippi. Most of this information was obtained in the form of full-scale map negatives that were combined photographically with EH&A's data overlays to produce the final large-scale maps. Only selected categories of information were combined on the base maps in order to provide adequate visual landmarks while maintaining a high degree of legibility for the data overlays. For example, hydrography, topography and bathymetry have been illustrated on the base maps, while transportation networks and cities have not. In order to improve the legibility of the data overlays, a 50-percent dot screen was applied to the base maps so that they would appear as background information relative to the unscreened data that is the main theme of each map sheet. The base layer of the small-scale maps (Volume V) was digitized by EH&A on a PC-based Micro-Station from the 1:250,000-scale USGS topo-bathy series maps.

2.4.2 *Production of Data Overlays*

Production of the data overlays was accomplished using Micro-Station computer-assisted-design (CAD). Geological and archaeological (for Washington and Oregon) information was initially mapped on paper copies of the 1:250,000-scale USGS topographic maps. The data contained on these maps was then digitized by EH&A onto Micro-Station. Prehistoric site locations for California were mapped by computer using an ASCII file, derived from the site database, containing state site numbers and Universal Transverse Mercator (UTM) coordinates. Once project information was in a digital format it could be customized as necessary to produce both large-scale and small-scale data overlays for each map unit, with different levels of information appearing on the two versions, the former for MMS use and the latter for public dissemination.

3.0 SUMMARY OF FINDINGS

3.1 Geology

3.1.1 *Post-Wisconsin Geologic History*

The maximum late Wisconsin lowstand of sea level occurred between approximately 20,000 and 17,000 years before present (B.P.). The 10,000 B.P. Pleistocene/Holocene boundary would actually have occurred in the middle of the post-Wisconsin transgression commonly referred to as the Holocene transgression. While the 10,000 B.P. boundary does not correspond to a sharp change in the rate of sea level rise, it is the commonly accepted date for the beginning of the Holocene and is accepted for the purposes of this study.

In the western portion of North America, three major tectonic plates are recognized: the Pacific, Juan de Fuca, and North American. The tectonic control of the study area north of the Mendocino fracture zone appears to be dominated by the underthrusting of the Juan de Fuca plate beneath the North American plate. The portion of the study area south of the Mendocino fracture zone is dominated by transform boundaries separating the Pacific and the North American plates (including the San Andreas fault system). The continental margins of the study area north of the Mendocino fracture zone may be evolving from a compressional underthrusting to a transform strike-slip tectonic regime resulting from extensional forces and the coupling of the Juan de Fuca and North American plates. The tectonic, depositional, and magmatic Cenozoic history of the northern half of the study area has been affected by episodic periods of underthrusting, transcurrent faulting and extension between the Pacific, Juan de Fuca (Farallon), and North American plates. Periods of subduction were interrupted by major right-lateral, strike-slip faulting.

Changes in Pleistocene climate caused glacio-eustatic sea level fluctuations which strongly influenced coastal margins around the world. Periods of glaciation were associated with marine regressions and low stands, while interglacial stages were accompanied by advancing seas and high stands recorded by elevated, wave-cut terraces occurring along the coast. The post-glacial period in the study area is characterized by extensive deposition, changing regimes of sedimentation, and both sedimentary progradation and erosion.

3.1.2 *Holocene Sediment Isopach Data*

Several factors control the thickness of unconsolidated sediment accumulation including sea level fluctuations, sediment sources and quantity, currents, and surface morphology. The most important of these factors is changes in sea level. Holocene isopach data for the northern portion of the study are not available or are combined with Pleistocene units. The data in this area are derived from surficial geologic maps and descriptions of Holocene sediment isopach. Holocene sediment isopach in the Washington area is greatest in the area north of the Columbia River mouth and is estimated at less than 20 to 30 meters (m) thick.

Data for offshore Oregon areas indicate that sediment is thinner than 20 m. In the southernmost portion of the study area, late Pleistocene sediment isopachs have been combined with Holocene sediments because of the lack of definition in the high-resolution seismic records. Maximum thickness of these sediments is greater than 33 m.

3.1.3 *Typical Shelf Characteristics*

The modern continental shelf is a shallow submerged platform which slopes gently seaward. The continental shelf in the study area (west coast) is narrower (average 30 to 35 km) than shelves found in other parts of the world (average 73 km) and slightly steeper due to its active tectonic setting. Also, sedimentation rates are higher along the west coast than along passive margin shelves.

Sedimentation on and the physiographic form of the shelf have been significantly controlled by geologic factors (i.e., tectonics) and to a lesser degree by oceanic processes such as currents and storms. Repeated sea level rise and fall during the Quaternary Period have reworked relict sediments smoothing the shelf's surface by filling in depressions. Sea level fluctuations worldwide have produced a characteristic shelf facies with a nearshore sand facies, mid-shelf mud facies and outer shelf relict facies. In places on the west coast, the mid-shelf facies covers the outer shelf and shelf break. The reworking of sediments on the shelf has probably destroyed many prehistoric habitation sites except in areas of rapid, but calm, sedimentation.

3.2 *Prehistory*

The assessment of the prehistoric archaeological potential of the OCS from Morro Bay to the Canadian border focuses on two major elements. The first element is the gathering and evaluation of data relevant to the sorts of archaeological sites which might be expected on the OCS. In addressing this question, known archaeological site distributions, ethnographic data, and current archaeological settlement pattern models are utilized. The second focus is on the destructive forces associated with sea-level rise and subsequent subtidal processes. An emphasis of this component is the identification of landform associations that might offer protection from erosional regimes, thus protecting the archaeological resource base.

It should be noted that, while the emphasis of these discussions is on early (i.e., late Pleistocene/early Holocene) coastal populations, more recent archaeological sites might also have become submerged on the OCS due to complex tectonic processes. Evidence is available for localized Holocene uplift and subsidence that complicates the picture to some degree. Nonetheless, the overwhelmingly important process to consider is generalized sea-level rise due to the dissipation of the Pleistocene continental glaciers.

3.2.1 *Early Human Habitation of the Coast*

Discussion of the early prehistory of the Pacific coast of North America is centered on three major themes: the timing and source(s) of the first human populations; the extent of maritime adaptations; and the relationship of the early prehistory to the subsequent appearance of the ethnographic cultures of the region.

While the earliest human populations of the coast are invariably assumed to be derived from Asia, there is considerable uncertainty regarding the timing and the route or routes of their movement into this region. Based upon data from elsewhere in North America (Shutler 1983; Irving 1985; Carlisle 1988), the arrival of these first populations probably occurred at the end of the Pleistocene, although a slightly earlier date is also possible. For much of the northwest coast, the actual circumstances of an arrival at this time may have been constrained by the presence of the late Pleistocene Cordilleran Ice Sheet. At its maximum, various lobes of the Cordilleran Ice Sheet covered virtually all of the northwest coast between southeast Alaska and northwestern Washington (Mathews 1979). The last major advance of this glacial ice terminated ca. 14,000 years

ago, and by ca. 12,000 years ago, migrating peoples with the appropriate technology could have spread down the coast from the north, or to the coast from unglaciated areas to the south or east, or both (Fladmark 1983).

The traditional view of northwest coast culture was expressed by A.L. Kroeber (1939:28) who suggested that it was "...originally a river or river-mouth culture, later a beach culture, and only finally and in part a seagoing one." This interpretation clearly implies that the early prehistory of the coast is derived from the interior. Similar arguments have been made for the California coast, under the assumption that the earliest inhabitants of the state were primarily hunters of large game (Moratto 1984; Warren 1967). It has been suggested that river mouth, lagoon-oriented adaptations emerged as a response to mid-Holocene environmental change.

The increased accumulation of archaeological data in recent years, from both within and beyond the region, has complicated this picture considerably. During the 1970s important contributions to our view of coastal prehistory were offered by Charles Borden (1975) and Knut Fladmark (1975). Both of these researchers saw the prehistory of the northwest coast as the product of the fusion of at least two different cultural traditions. Both suggested that there was an early coastal tradition which first appeared on the northern coast and spread south, and that there was an early interior tradition in the south which spread to the west (i.e., the coast) and then to the north. "Classic" northwest coast culture is seen as a product of the merging of these separate traditions within the context and potentials of the later prehistoric environment of the northwest coast.

More recently, Roy Carlson (1983; n.d.) has offered a similar, but more complex variation on this theme of multiple cultural traditions during the early prehistory of western North America. Carlson (1983:75) suggests that, in fact, at least four major basal cultures or cultural traditions existed in the region; they include the two noted by Borden and Fladmark, and two additional traditions. These traditions are four somewhat different technological complexes distributed over adjacent geographic areas. Further, Carlson suggests that a distributional correlation between these early traditions and the major language groups of the historic period may be evidence that the various traditions were borne by the ancestors of these groups. Although many archaeologists doubt that a strict correspondence between these traditions and language groups can be supported, because of the broad scope and detailed basis of Carlson's model, it is worth considering here.

The Fluted Point Tradition (FPT), though widespread over much of North America, is only minimally represented on the northwest and California coasts. It is marked by the presence of large projectile points with distinctive basal fluting. Many regional variants of the tradition exist, probably the best known being the *Clovis* points of the southwest and the Great Plains (Wormington 1957; Hayes 1980). Potentially the earliest cultural tradition in North America, its practitioners appear to have been present by ca. 11,500 B.P. However, these peoples seem to have had relatively little interest in our coastal area. To date, for instance, no unequivocal FPT sites have been demonstrated on the coast. Carlson (1990) reports that 11 undated fluted points have been found in coastal regions, but none have been found in association with other potentially early cultural materials. The fluted points at the Borax Lake site in California's north Coast Range have been dated to as early as 10,000 B.P., but these appear to be associated with interior cultures with lakeshore-oriented settlement patterns. Whatever the nature of their presence, it seems likely that the bearers of this tradition entered the region from the interior and that their forays here may have been brief. Carlson suggests that the FPT peoples may have been ancestral to the Macro-Algonquin language group; there is currently little basis to suggest that they had much influence on subsequent cultural developments on the Pacific coast.

The Stemmed Point Tradition (SPT) is primarily a culture of the interior of western North America. Also quite early, it appears to be present by ca. 11,000 B.P. The tradition is represented by assemblages marked by large rectangular-stemmed or weakly shouldered projectile points. Like the FPT, the SPT has several regional variants; in the northwest it is often referred to as Lind Coulee or Windust phase (Rice 1972), and in the southwest as Lake Mojave (Davis 1967; Warren and Crabtree 1986). While largely restricted to the interior, points of this general type have been reported from coastal Oregon in the vicinity of the Columbia River mouth (Minor 1984). Similar specimens may also occur in sites in southwestern Oregon (Brauner and Nisbet 1983) and in southwestern Washington (Daugherty et al. 1987). Given their occurrence, Carlson suggests that the SPT in the northwest approximates the distribution of the Macro-Penutian language group, but other researchers have suggested different linguistic associations. For instance, Moratto (1984) suggests that Lake Mojave complex peoples were speakers of the Hokan stock.

Carlson's Pebble Tool Tradition (PTT) is centered on the southern northwest coast and is essentially the early southern tradition referred to by both Borden (1975) and Fladmark (1975). It is marked by the co-occurrence of unifacially flaked pebble tools and leaf-shaped bifaces. While not well-dated, there is some reason to believe that it may be slightly more recent than either the FPT or SPT; it is certainly in place by ca. 9,000 to 10,000 B.P. In this regard, it was formerly thought that an early expression of this tradition - the Pasika Complex - lacked bifacial tools and was of Late Pleistocene age (Borden 1968), but more recent work has shown that this is not the case (Haley 1988). PTT sites occur widely on the southern northwest coast and similar assemblages are known throughout the interior of the Pacific Northwest where they are referred to by such names as Old Cordilleran culture (Butler 1961), Cascade phase (Leonhardy and Rice 1970), or Milliken phase (Borden 1960). Rather than being an early interior culture which adapted to the coast, Carlson sees this tradition as an early coastal culture which spread up the rivers and into the interior. He suggests that the bearers of the PTT were the ancestors of the Salish, and possibly Wakashan, language groups.

The last member of this group is the Microblade Tradition (MT), marked by a true blade-and-core technology utilizing small parallel-sided blades for a variety of cutting and piercing tools. It is earliest on the northern part of the northwest coast and is essentially the early northern tradition referred to by both Borden (1975) and Fladmark (1975). Here, it dates between ca. 8,000 and 10,000 B.P. Similar microblade industries are also known from Alaska and northeast Asia (Smith 1974). On the northwest coast, more southerly expressions of the tradition are progressively more recent in age. It is likely that the MT people were maritime oriented, as many of their earliest sites could only have been occupied with the use of watercraft and a reliance on marine resources. While microblade technology appears to have spread widely after the Mid-Holocene, Carlson notes that its early distribution was limited to that area occupied historically by Tlingit, Haida, and Athapaskan peoples. As such, the MT may represent the early ancestors of all of these peoples.

In sum, the four identified traditions appear to have reached the coast by at least two different routes over a period that might represent as much as several millennia. Each had its own impact on the subsequent culture history of the region, ranging from considerable to almost none at all. The FPT and SPT both appear to have reached the coast from the interior. These were probably carried by descendants of earlier interior hunting cultures from Beringia and northeast Asia, and are therefore closely related to other Paleo-Indian peoples over much of North and South America. In contrast, the PTT and MT appear to have arrived slightly later and seem to have spread first down the coast, and then up the river valleys into the interior. They may have been derived from earlier coastal cultures from Beringia and the Asian north Pacific region, and their bearers may have been relatively less closely related to most other New World Paleo-Indian

peoples. All such early cultures appear to have arrived (or come and gone) by ca. 8,000 B.P. Subsequent *in situ* cultural developments then tended to homogenize cultural differences through the processes of adaptation and acculturation.

3.2.2 *Settlement Patterns Through Time*

In light of the relatively limited and biased data actually available, prehistoric land use systems of the southern northwest coast can be considered only in very broad terms. The available data from the Oregon and Washington coasts, is limited in total extent, heavily biased toward certain types of sites, and confined largely to the last ca. 2,000 to 3,000 B.P. Notions of earlier settlement patterns are mostly projections of relatively better-known early traditions from nearby areas.

Early-human studies summarized above suggest that as many as four separate cultural traditions (or cultural adaptations) may have been present over at least portions of the Northwest Coast prior to ca. 8,000 B.P.; the timing of the first appearance is unknown, but certainly was no later than ca. 11,500 to 12,000 B.P. Unfortunately, relatively little is known about any of their settlement and subsistence systems. It can safely be assumed that the earliest inhabitants of the coast utilized a range of terrestrial and riverine resources. What role marine resources may have played is less clear, since the early coastal sites have all been submerged. There is some basis to argue that they may have been important to at least some early cultural groups.

Theoretically, these earliest occupants could have been either logistically mobile collectors or residually mobile foragers. In fact, Binford's (1980) original discussion of the forager-collector model includes the view that there was something of a latitudinal dimension to the global distribution of these systems. Within this context, Binford (1980:15) argues that collector-type strategies are more likely to occur at higher latitudes. Essentially this view has been expressed for the northwest coast by Aikens et al. (1986). In contrast, however, most recent ideas about the early prehistory of this area visualize forager-type strategies (e.g., Borden 1975; Fladmark 1975; Schalk 1977; Thompson 1978; Carlson 1983; Minor 1983; Lyman and Ross 1988).

In support of the view of early northwest coast foragers, it is worthwhile to note that the few available materials appear to be expressions of early cultural traditions which occurred widely in western North America. Land use reconstructions for such early cultural traditions as the FPT, SPT and PTT invariably view these people to have been foragers (Haynes 1980; Bryan 1980; Carlson 1983). If present in coastal areas, it seems reasonable to consider that representatives of any of these traditions would have incorporated marine resources as one or more elements of their foraging strategies. Thus, if these cultural traditions are, in fact, evidence of the earliest human inhabitants, then the first occupants of the northwest coast probably were characterized by forager-type settlement and subsistence systems. Alternatively, if a collector-type system is visualized for the coast's earliest occupants, then it must be acknowledged that it would probably have been unrelated to any of the above-mentioned early traditions (as they are currently conceived). Visualizing an early coastal-based collector-type adaptation, therefore, may imply either the presence of yet another early cultural tradition on the northwest coast or a problem with our current reconstruction of one or more traditions.

At present, the interpretation that the earliest occupations of the northwest coast were probably by forager-type systems seems most plausible. Individual human groups were probably relatively small and were marked by a high degree of residential mobility. Following Binford (1980), sites created by them were limited to two basic types: residential base camps and loci of resource procurement. Architecture and other aspects of material culture inventories were probably relatively limited. Since food-storage technologies were not employed to any significant

degree, hunting, gathering, and other food-producing activities were conducted regularly throughout the year.

As compared to these early occupations, late prehistoric settlement and subsistence systems on the northwest coast are much better documented, but significant uncertainties are apparent here as well. It is clear that the latest (i.e., ethnographic) systems were of the collector-type. However, when and how such collector-type adaptations developed and what their evolutionary relationships to the earlier forager- (or collector-?) type adaptations may have been is largely unknown.

The available data from this region suggest that forager-type systems, including some use of marine resources, were present as early as ca. 8,000 years ago. The true extent of early maritime adaptations cannot be determined without investigating sites on the OCS. Limited Mid-Holocene data suggest that this pattern continued with an apparent broadening and intensification of the use of marine resources. Notable is an apparent increase in the use of marine shellfish beginning ca. 5,000 years ago when sea level began to stabilize near its present level. Stabilization of sea level may have resulted in a more productive and reliable resource base. By this time, virtually the entire range of ethnographic resources was probably being utilized and the question becomes: when did use of these resources within a forager-type system shift to their use within a collector-type system? In principle, this shift should be marked by such attributes as larger sites with evidence of substantial houses, evidence for food storage, evidence of mass harvesting, and a diversification of settlement types. Again following Binford (1980), collector-type systems also utilized field camps, stations, and caches, in addition to their residential base camps and procurement locations. Occupations which appear to represent collector-type systems are known from several places along the coast by ca. 3,000 years ago and researchers (notably Fladmark 1975, 1978, 1982) believe that the apparent increase in shellfish use ca. 5,000 B.P. is associated with the onset of this land use system change.

The settlement and subsistence pattern generally proposed for the Late Holocene is much like that described for the ethnographic cultures of the northwest coast. Central to this view is a nuclear (village/residential base camp) mobile (individual family units) land use strategy which facilitated changes in group structure as resources became seasonally available. The idealized pattern is for the group to be concentrated in its residential base camp during the winter months (i.e., the "winter village") and for individual family units to radiate out of the base camp to other smaller localities during spring, summer, and fall. In fact, local ethnographic realities present a number of variations on this basic theme.

Further, there is some reason to believe that the ethnographic settlement pattern was a response to protohistoric-early historic conditions, chief among them being a substantial reduction in population due to introduced diseases. Draper (1988) has recently argued this case for the southern Oregon coast, but his concepts are probably relevant to the entire northwest coast region. Basic elements of his late prehistoric settlement model include:

-(1) that prehistoric population densities were much higher than that suggested in the ethnographic literature;
- (2) that because of the resource base exploited prehistorically and the distribution of these resources across the landscape, the settlement pattern was essentially a linear one rather than a radial or planar one;
- (3) that residential mobility was low, characterized by numerous villages largely occupied year round by small family groupings perhaps confined to well-defined territories; and
- (4) that because of

the above elements, productive site locations (villages or temporary camps) that provided access to a wide array of resources were highly valued and thus repeatedly occupied and served multiple functions in the settlement systems (Draper 1988:269).

In California, current knowledge of late Pleistocene/early Holocene settlement systems is very incomplete. Most data for early occupations come from the central California region, where evidence indicates that marine resources were used as far back as 8,000 B.P. and possibly earlier, with a well-developed maritime economy in place by about 5,500 B.P. Specific settlement systems used during this time are unclear, but favored locations include embayments, lagoons, and estuaries, which to some researchers suggest similarity with the early lacustrine adaptations found further inland. It has been suggested that the high productivity of such environments, particularly for relatively small populations, may have supported near-sedentary settlement systems; if so, considerable length of occupation and reoccupation of coastal residential sites is implied.

Around 3,700 B.P. in central California, some economic diversification apparently took place, with the establishment of numerous sites further inland. Large, permanent villages appear a short distance inland, in locations affording access to both terrestrial and marine resources. This development seems to mark the emergence of "collecting" systems in this area, and is likely quite similar to those patterns observed ethnographically.

Along the coast of northern California, no components have been found dating to earlier than 2,200 B.P. This does not, however, demonstrate that the coast of northern California was unoccupied during the early Holocene, since a number of factors, such as inundation by rising sea levels, erosion, or relatively fewer archaeological investigations, may have resulted in the lack of known early components. Nevertheless, the heavy preponderance of early components in central and southern California suggests strongly that coastal northern California, while perhaps not completely unoccupied, was not occupied as intensively as other portions of the coast during the early period. If present, this early adaptation along the northern California coast was probably characterized by small groups with a relatively high degree of residential mobility. Available data for later settlement and subsistence patterns seem to indicate a gradual intensification of use of coastal resources.

3.2.3 *Potential for Prehistoric Sites on the Continental Shelf*

This review and analysis of the potential for submerged prehistoric archaeological sites on the OCS within the study area suggest that the potential for such deposits is real, although probably limited to specific landform associations. In evaluating this finding, however, it must be emphasized that the currently available archaeological and geological databases which constitute the context of the study are very limited, generalized, and lacking in localized details: (1) no intact prehistoric sites have been reported on the OCS, (2) prehistoric settlement patterns for the periods in question are almost entirely unknown, (3) there is a paucity of measured sea-level curves, (4) high-resolution seismic data coverage is spotty, and (5) almost no vibra-coring or drilling has occurred on the shelf. All such conditions impose important restrictions to our ability to predict potential site locations. Further, it should be noted that there are significant technological limitations to archaeological survey for prehistoric sites in the subtidal setting of the OCS; this condition also imposes important restrictions.

In order for archaeological deposits to occur anywhere, two basic conditions need to be met: there must have been human activity which produced physical remains, and there must

have been a subsequent sequence of environmental conditions which preserved rather than destroyed those remains. This observation is particularly relevant to the archeological potential of the OCS in that a variety of mechanisms have likely affected prehistoric site distribution on the OCS. While the processes and specific circumstances of inundation may be quite variable, in most cases they are likely to be highly destructive to archaeological materials and sites. A number of both chemical and mechanical effects are probably involved, but the most important single factor is undoubtedly wave energy. The chemistry of inundated sites can actually be a positive factor for preservation. Peat deposits and anaerobic muds found in offshore environments are particularly favorable for the preservation of organic site materials. Wave energy can physically destroy cultural objects and completely rework and scatter cultural deposits. Further, in considering the impact of wave energy, it is important to stress that the extent of impact is influenced not simply by the "normal" wave energy regime, but rather by the maximum wave energy occurring while the cultural material is present in the intertidal setting. Winter storms and periodic seismic events can produce brief wave-energy regimes many orders of magnitude greater than those normally associated with Pacific coast beaches.

Opinion is divided as to the effects of inundation and waves on archaeological sites, but there is a general consensus that many prehistoric sites are likely to have survived the inundation process in a relatively intact state. For example, Kraft et al. (1983:116) concluded that "...the possibility of eventual discovery of sites [on the continental shelf] is high." Their position is supported, although qualified somewhat, by Inman.

...the probability of recovering evidence of habitation representative of times of rapid sea level change is not high. Still-stands in sea level, on the other hand, lead to a stability of terrace formation and coastal form that favors the concentration and permanency of cultural deposits... During still-stands... lagoons and ecological zones are established, and become stabilized, supplying resources of interest to early peoples... As a consequence, the identification of shorelines associated with still-stands in sea level is the most logical first step in the process of locating areas of human activity on the shelf (Inman 1983:39-40).

Although paleo-shorelines associated with still-stands would seem to be likely areas for both the occurrence and preservation of prehistoric sites, Masters cautions that still-stands are the most destructive period for sites occurring in an exposed beach context. Nevertheless, "...the evidence suggests that some prehistoric sites along the southern California coast may be expected to survive a marine transgression relatively intact" (Masters 1983:211).

The probability for survival of intact inundated terrestrial locations is likely to be directly related to the degree of wave energy to which cultural materials are exposed during the inundation process. In a general sense, the degree of wave-energy exposure is related to coastal morphology; thus it is possible to identify landforms which were probably attractive for human occupation and which would offer protection to cultural deposits from high wave-energy regimes during inundation. Such features include: submerged river valley systems, embayments, and island complexes. These landforms are considered to be potentially sensitive for the presence of archaeological sites; landscapes lacking such features are not. Furthermore, the presence/absence of Holocene sediments on the OCS is another useful measure of site potential. Intact inundated archaeological sites can only occur in areas where there are sediments to protect them. Exposed bedrock surfaces have little potential in this regard; thus, isopach data has been overlain upon the

known distribution of sensitive landforms, and those which lack sediments are considered to have a reduced potential for containing intact archaeological deposits.

Flemming (1983) ranked various coastal landforms regarding the preservation potential which they afford to archaeological sites during the inundation process and discussed known examples of submerged sites preserved in such settings. Citing evidence of "...lithic and Bronze Age (3rd-2nd millenium) sites...found from the surf zone down to 25 m..." (1983:135), Flemming concluded that:

Lithic site structures and artifacts, uncemented walls, burials, hearths, middens, food remains, and tools and other artifacts can survive in stratigraphic context in the sea or below the coastal groundwater table after a marine transgression... Such remains are protected either because the environment is low energy (ria, lagoon, estuary, karstic cave, archipelago), or because the beach gradient provides a protective cover of sediment (Flemming 1983:166).

The most widespread sensitive features are submerged river valley systems. Such features are associated with every modern river system in the region. In terrestrial, near-coastal, settings, these environments are known to have been important for human occupation, and their lowermost courses must be so regarded also. Some paleo-embayments were present, but they appear to have been limited. A particularly large structure of this type was present on the central Oregon coast prior to ca. 10,000 years ago, although an apparent absence of Holocene sediments over some of this area probably reduces its potential somewhat. Given uncertainties about the timing of earliest human occupation, it is also possible that this structure is too old to have been occupied. The prehistoric shorelines of Grays Harbor and Willapa Bay on the southern Washington coast are important younger features. They have a considerable mantle of Holocene sediments and should be regarded as having a relatively high potential. Island complexes make up a third group of sensitive landform. These also appear to have been relatively uncommon and largely restricted to the southern Oregon coast.

In California, as in Oregon and Washington, submerged river valley systems are the most common of the sensitive paleo-landforms, being found offshore of most large terrestrial drainages. Paleo-embayments were also present, but were primarily associated with later shorelines. The most extensive of these is San Francisco Bay, which began forming around 10,000 B.P. but reached maturation only comparatively recently. Islands are relatively uncommon, and where identified are usually small. The sensitivity of many of the identified island areas within the OCS study area is reduced by the lack of protective sediment mantles.

3.3 Maritime History

3.3.1 Major Themes and Trends

Maritime affairs played a major role in almost every aspect of the history and development of the Pacific coast. The maritime history of the study region, as may be true of the entire world, has been shaped to a large degree by commerce. The desire for new riches combined with the economic advantages of finding the fabled Northwest Passage, provided the stimulus for the earliest period of exploration by the Spanish along the coast of the study area beginning with the voyage of Cabrillo in 1542. The initial enthusiasm of these early explorers was dampened by the realities of the Pacific Coast. It was soon discovered that the easy riches

Meso-America were not to be had from the Indian villages to the north of Mexico, in that area called California, nor was the Northwest Passage to be found.

The second phase of Spanish exploration to the far north, however, was largely stimulated by the desire to secure the California coast for strategic reasons. The Spanish soon realized the importance of dominating the California coast so that homebound galleons from Manila could call for reprovisioning and repairs before making the final leg of their journey to Mexico. The voyages across the Pacific were arduous, and by the time the galleons reached the North American coast, the crews and ships were often in pitiable condition. The Manila galleons continued to be an important part of the Spanish economy and made their annual voyages until almost the end of the Spanish colonial period in America.

The Spanish monopoly along the western shore of the New World came to an end in 1578 when Francis Drake rounded Cape Horn and began attacking Spanish settlements and ships as he made his way north along the coast of South America. It was on this voyage, in June 1579, that Drake landed in an inlet north of San Francisco Bay, presumed to be present-day Drakes Bay, to repair and reprovision his ship.

Spanish exploration and mapping along the coast of Alta California and the Pacific Northwest had gone on steadily for nearly 100 years, abruptly stopping following the voyage of Vizcaino in 1603. Between the return of Vizcaino in 1603 and Bering's voyages in the early eighteenth century, the Spanish were effectively the sole European power on the Pacific coast. Unfortunately for them, they did nothing to consolidate their advantages and the Pacific coast was left much as they had found it. By the time they reacted to the entry of other powers, the Spanish Empire had grown too weak to stop the trickle of explorers which was soon to become a flood of traders, merchants, and eventually settlers.

The actual economic possibilities of the Pacific Northwest did not begin to be realized on a large scale until after the results of Captain Cook's visit to the region in 1778 had been published. The economic potential of the trade in sea otter pelts was the impetus for rapid expansion into the area by fur trading companies. Sea otters have been called the lodestone which first brought Europeans to the Pacific Northwest in large numbers.

One of the side effects of gaining independence in the Revolutionary War was that Americans lost access to the British markets they had depended upon heavily for overseas trade. With their traditional markets closed, many American merchants and sea captains began to look to the Pacific coast. The Pacific Northwest lumber trade marked the beginning of continuous occupation and economic development of the Pacific northwest coast. Almost three centuries after the first European explorers had arrived on the west coast, there were so few people living to the north of Mexico that even in the most heavily populated areas, the demand for wood was minimal. As the population began to increase, the need for lumber grew. The first sawmill in regular operation in the Pacific Northwest was opened in 1827.

Like all aspects of life on the Pacific coast, the lumber business was transformed by the discovery of gold in the race of Sutter's Mill in 1848. As thousands of hopeful miners swarmed into California in search of gold, even the most commonplace items took on new value and wood products were no exception. San Francisco was bursting with new arrivals in need of shelter, the miners needed wood for their diggings, and building materials of all sorts were in short supply. Although there was certainly no shortage of standing timber, lumber production capacity was completely overwhelmed by the sudden demand. By the 1880s, the maritime timber trade in the Pacific Northwest had begun to take on its modern form.

The boom days of the gold rush did not last beyond the early 1850s, but during that short heyday, the isolation of the Pacific coast was broken. San Francisco was established as the major commercial city west of the Mississippi River. The post-gold rush economy of the Pacific

coast continued to be largely maritime-based. The whaling ports of California continued to grow in importance throughout the latter half of the nineteenth century, as the whaling status of New Bedford began to decline. Although the American shipping industry went into a depression during the latter part of the 1850s that lasted through the Civil War, the maritime economy of the Pacific coast emerged from the war in better condition than the United States merchant marine as a whole (Fairburn 1945:951). Both grain and lumber products became major worldwide export items from the Pacific coast during the latter half of the century.

3.3.2 *Potential for Historic Sites on the Continental Shelf*

Historic archaeological sites on the OCS consist primarily of shipwreck sites. A great variety of ships have wrecked along the Pacific coast since the days of the earliest explorers. The earliest known shipwreck to have occurred in the study area is that of the Manila galleon *San Agustin*, lost in Drakes Bay in 1595. Since that time, literally thousands of vessels of many types and descriptions have wrecked along the Pacific coast and in the study area. An integral part of this study entailed the compilation of a database listing shipwrecks that occurred in the study area prior to the end of World War II. The shipwreck database contains an estimated 4,676 unique wreck listings for the Pacific coast of the United States. Of this number, 826 listings pertain to wrecks in southern California that had been entered into the database as part of an earlier MMS-sponsored study covering that region (Pierson et al. 1987). The database contains records for an estimated 3,850 unique wreck events from within the study area. The database admittedly contains a subset of the total shipwreck population; however, this number is believed to represent a significant proportion of historic vessels wrecked in the study region. An important exception is the large number of small watercraft, both indigenous and historic, including most fishing vessels, which were never registered with a governmental body and, thus, were never recorded in history. The types of vessels most characteristic of the Pacific coast, and of the shipwreck database, during the study period are discussed in Volume IV. Due to the nature of the various data sources used to compile this database, the number of these vessels which were removed for salvage or refloated and repaired is uncertain; thus, the exact number of archaeological wreck sites represented by the database is unknown.

The distribution of known shipwreck sites in the study area has been illustrated on a series of Historic Site Location Maps in Volume V. Glancing at these maps, one can see that vessels tend to be lost with the greatest frequency adjacent the coast. The frequency of vessel losses increases markedly along headlands and harbor approaches and in inner harbor waters. The major factors contributing to this distribution are related to vessel traffic patterns and to the physical environment. Vessel traffic and navigational hazards are concentrated in the vicinity of the coast. This is especially true in the vicinity of harbors and headlands. It is estimated that between 80 and 90 percent of all vessel losses in the study area occurred in less than 10 m of water in what has been referred to throughout this study as the nearshore zone.

Offshore searanes, while having a relatively lower historic site potential when viewed in comparison with the nearshore zone, may have a significantly higher potential for the occurrence of shipwrecks than do offshore areas located outside of traffic lanes. The potential for the occurrence of significant historic sites in offshore areas should not be ignored or downplayed. Even though the likelihood for wrecks occurring in such areas is relatively low, the research potential of such wrecks may be relatively high due to the higher potential for preservation of substantially intact wrecks occurring in low-energy offshore waters. This is especially true in areas having a relatively high rate of sediment deposition where sites are likely to become buried. Deep-water wrecks would be less likely covered by sediments; however, they would not be subjected to

the highly destructive wave energy of the nearshore zone. Furthermore, the cold waters of the region do not allow shipworms (the wood-boring mollusk *Teredinidae*) to breed, thus wooden elements should survive fairly well. Being in a deep-water, sediment-starved environment, wrecks are more likely to project above the bottom, increasing the likelihood of detection on side-scan sonar images.

4.0 CULTURAL RESOURCE MANAGEMENT (CRM) ON THE OCS

The role of cultural resource management on the OCS has evolved significantly since the first archaeological surveys were conducted there in the mid-1970s. The legal requirement to protect cultural resources there is the same as on the continent, although it has been an uphill struggle for archaeologists to secure enforcement of this requirement. Technology for conducting underwater investigations continues to improve at a rapid rate. The current state of affairs of cultural resource management on the OCS are discussed in the following subsections, including: a summary of CRM legislation as it applies to the OCS archaeological program; underwater technology for investigating both prehistoric and historic sites on the OCS; and current MMS archaeological requirements for the Pacific Region OCS.

4.1 CRM Legislation

Responsibility for the protection of archaeological resources on the OCS from federally sponsored or permitted actions falls entirely to the federal government, since the OCS, by definition, starts beyond the 3-mile limit of state jurisdictional waters. As mentioned earlier, there are three primary legislative acts that mandate this responsibility upon federal agencies. These are the National Environmental Policy Act, the National Historic Preservation Act, and the OCS Lands Act. It is the policy of MMS to consult the appropriate State Historic Preservation Offices regarding all Federally permitted or Federally sponsored OCS activities.

With the passage of the Abandoned Shipwreck Act in 1987, ownership of and responsibility for historic shipwrecks inside the 3-mile limit was transferred to the state governments. Under this law, historic wrecks occurring within three miles of the U.S. shoreline, but within federally owned waters (e.g., adjacent National Park Service lands), remain the property of and responsibility of the federal government. Federally owned waters inside the 3-mile limit include all waters within 3 miles of federally owned shorelines. Throughout the study area, there are hundreds of miles of national seashore. Historic shipwrecks located within three miles of these federally owned lands are the property of the federal government and cannot be disturbed by any activity without the effects of such action first being considered by the appropriate federal agency under Section 106 of the National Historic Preservation Act.

4.2 Detection and Investigation of Submerged Sites

4.2.1 *Remote-Sensing Technology and Phase I Survey*

Phase I archaeological survey on the OCS implies much the same thing as it does on the continent. The object of this level of field research is to locate archaeological sites within a particular area. The most obvious difference between marine and terrestrial surveys is, of course, technological. The fact that the OCS survey areas are covered by ocean prohibits one from visually searching for sites. Remote-sensing technology, borrowed from the geophysical industry, replaces the shovel and screen of the terrestrial archaeologist.

Another major difference between archaeological surveys underwater versus on land is that, when the underwater survey is completed, the archaeologist has still not seen any of the archaeological sites in the survey area. Instead the archaeologist sees images or signatures on instrument computer screens and instrument charts. These images, consisting of magnetic anomalies, acoustic shadows on side-scan sonar charts, and representations of geologic strata on

sub-bottom seismic profiles, must be interpreted by the archaeologist to determine whether any might indicate the presence of an archaeological site on the bottom.

The subject of remote-sensing data interpretation is discussed in Section 5.1 of this volume. The remainder of this discussion will focus instead on the current state of technology and methods used for Phase I marine archaeological surveys. There are a number of instrument manufacturers producing remote-sensing equipment, each offering slightly different variations upon essentially the same technology; thus, no mention is made here of specific manufacturers.

The three most useful remote-sensing instruments for conducting marine archaeological surveys are the proton precession magnetometer, side-scan sonar, and sub-bottom seismic profiler. Recording fathometers are frequently used on such surveys as well. Their usefulness is somewhat secondary in the search for sites, although they can be helpful in the identification of submerged islands that may offer potential site preservation environments. Such features should also be visible on sub-bottom records. Fathometers are most helpful in providing both assistance in the interpretation of the other instrument records and information useful in planning future phases of archaeological investigations.

The magnetometer measures the earth's magnetic field in the immediate vicinity of its sensor in units referred to as gammas. The intensity of the earth's magnetic field in the vicinity of the study area normally varies between 50,000 and 58,000 gammas. Localized sources of iron cause disturbances in the earth's magnetic field which are called anomalies. The amplitude of a magnetic anomaly is directly related to the mass of iron present and generally is inversely related to the cube of the distance from the sensor to the anomaly source.

Because magnetometers can indicate the presence of iron, they are well-suited to searching for sunken vessels. The amount of iron fittings in most historic wooden-hulled ships can readily be detected by a magnetometer provided the sensor is not too distant from the wreck. Previous investigations (e.g., Arnold and Clausen 1975; Arnold and Weddle 1978:197; Smith et al. 1987) have suggested research designs with a maximum distance of between 30 and 45 m between survey lines to ensure detection of the majority of historic shipwrecks. This close spacing facilitates recognition of anomaly patterns and more meaningful interpretations of survey data.

Normal deployment of a magnetometer for marine archaeological survey involves towing a submersible sensor behind the survey vessel along parallel linear transects. Due to the rapid fall-off rate in the amplitude of magnetic anomalies (inversely proportional to the cube of the distance), it is imperative that the sensor be kept close to the bottom and, thus, as close as possible to anomaly sources. It is equally imperative to keep the sensor from striking or dragging along the bottom as this can induce a great deal of noise in the record, making it unreadable and possibly damaging the sensor. Current MMS requirements in several OCS regions call for a maximum allowable height of 6 m above the bottom. In the past, sensor tow-depth generally has been judged by the amount of sensor cable played out behind the boat combined with the speed of the survey vessel. The accuracy of this method for determining sensor depth is highly questionable. Some recent models of magnetometers have pressure-sensitive depth meters attached to the sensors. When operating in deep water, the use of a depth meter on the sensor should be required in order to ensure proper control of sensor height so that anomalies do not go undetected.

Side-scan sonar is useful for detecting submerged historic sites such as shipwrecks when these sites project upward above the surrounding bottom terrain. Under certain circumstances it can also provide information regarding sea floor terrain that is useful in searching for prehistoric sites. One example of the side-scan sonar's usefulness for prehistoric site survey may be the recognition of karst features which often have prehistoric sites in direct association (Stright 1988; Dunbar et al. 1989). In the Pacific OCS region, sidescan sonar might have the

greatest application in mapping hard-bottom features, such as submerged rock outcrops, that might indicate locations of paleo-headlands.

Side-scan sonar operates by directing an acoustic signal downward and outward to either side from a sound source/receiver (towfish) that is towed beneath or behind the survey vessel. Objects projecting above the bottom act as good sound reflectors and return a strong signal to the receiver, while adjacent sound waves may strike the bottom either to be absorbed or deflected away from the receiver or to be reflected back to the receiver off of bottom terrain such as sand ripples. The resolution of the side-scan sonar record is determined by the frequency of operation, by the horizontal range selected, and by the height of the towfish above the bottom. A typical archaeological survey would use a frequency between 100-kHz and 500-kHz, the latter providing significantly higher resolution. Most side-scan sonars are capable of "seeing" several hundred meters to either side of the towfish, although the resolution decreases significantly as the range increases.

A strong acoustic return off of a solid vertical surface shows up on the side-scan's electrostatic chart paper as a dark image. An acoustic shadow may occur behind such an object, appearing as a light shape on the side-scan chart over the area where the sound signal is blocked by the protruding object. The size of the acoustic shadow can provide an indication as to the height of an object above the bottom. The relationship of side-scan images to the actual size and shape of the objects they represent is determined by the speed of the survey vessel, the horizontal distance of the object from the path of the towfish, and the straightness of the survey lines. Even slight turning of the towfish will distort the image of an object. If turning becomes too severe, the distortion can render common objects unrecognizable, thus straight lines are imperative when using side-scan sonar.

Recent side-scan sonar models offer automatic slant-range correction and chart speed correction (the latter to compensate for variations in the speed of the survey vessel). Together, these features allow the side-scan to represent objects on the bottom as precise scale images on the chart paper. Digital recorders are also widely available for side-scan sonar, allowing computer enhancement of images as well as the production of accurate mosaic maps of the sea floor.

Sub-bottom seismic profilers are the primary instruments relied upon for prehistoric site surveys on the OCS. These instruments operate in a wide range of frequencies, the different frequencies providing different depths of sound penetration into the bottom sediments. Very low frequencies can penetrate certain types of bottom materials to depths measured in hundreds of meters. The frequencies relied upon most often for archaeological survey fall into the 3.5-kHz to 7.0-kHz range and generally provide penetration measured in tens of meters.

Seismic profilers have a relatively narrow acoustic beam, thus they only provide a picture of sea floor stratigraphy immediately below the survey line. Survey line-spacing should be planned so as to allow several lines to cross over the smallest geologic unit which one is attempting to identify. When conducting prehistoric site survey, the primary geologic features of interest are drowned stream valleys that have been filled with Holocene sediment. Given a high-resolution seismic record, it may be possible to distinguish features as small as terraces or natural levees. In order to improve the chances of identifying features of this scale, sub-bottom survey lines should be run in a direction perpendicular to the expected orientation of such features, in this way allowing the maximum number of crossing lines.

In the Pacific OCS region, high-resolution seismic profiling might prove most useful in establishing the nature and thickness of Holocene sediment cover above the wave cut platform or below wave base scour. By comparison, lower-resolution seismic surveying could be useful in identifying geologic structures (e.g., folds and faults) that were important in controlling paleo-shoreline and embayment configurations.

In addition to the remote-sensing instruments mentioned above, some type of electronic positioning system is essential for recording the locations of features detected by the other instruments. For surveys conducted within two miles or so of the coast, or other stationary features such as islands or oil platforms, very precise positioning can be achieved using laser- or microwave-based range/azimuth systems in which a set of omnidirectional prisms (for laser reflection) or a microwave transponder is mounted to the survey vessel and tracked by a tripod-mounted survey station onshore. The survey station measures the distance (i.e., range; usually within a foot or less) to the prism or transponder and the corresponding azimuth at the same moment. Range/azimuth pairs are measured at predetermined time intervals and displayed on a digital readout.

Surveys that are conducted more than two miles offshore may be controlled using either a microwave-based range/range positioning system or a satellite positioning system. The geography of the coast may be a limiting factor in the use of a microwave system in some instances, since it requires good separation between shore-based transponders to attain the best results. Under optimum conditions using microwave, accuracy of 2 m or better should be attainable. The accuracy of satellite positioning systems at the present time ranges from about 5 m to 20 m. An accuracy of approximately 7 m should be attainable with the Global Positioning System (GPS) satellite network, using the GPS translocation technique for correcting positions. The translocation technique involves use of a second satellite receiver placed at a known fixed point which calculates correction factors and transmits these to the survey vessel on a continuous basis. The most accurate system possible, given the distance of a survey area from shore, should be used at all times when conducting archaeological surveys.

Due to the large quantity of positioning data that accumulates on even a small survey, it is absolutely essential to log positioning data on a computer. Use of a computer allows fully automated surveys and greatly simplifies the process of mapping remote-sensing data following the survey. Computers are doubly advantageous, since they also allow real-time display of vessel position along pre-plotted survey lines and can provide steering guidance to the helmsman. The latter feature is extremely helpful in maintaining straight survey lines and assuring even coverage of the survey area.

4.2.2 *Phase II Site Investigations: Ground-Truthing and Testing*

Phase II archaeological investigations generally entail limited site documentation to assess a site's significance and its potential for eligibility to the National Register of Historic Places (NRHP). The major difference between conducting such investigations underwater versus on land is that most underwater testing is performed on remote-sensing targets or anomalies that have not been confirmed as being archaeological sites. The term "ground-truthing" has come into common usage to describe the confirmation of anomaly sources. All remote-sensing signatures that can not be avoided by bottom-disturbing activities must be ground-truthed. Once an anomaly source has been confirmed as an archaeological site, documentation and National Register assessment would proceed as it normally would occur on any terrestrial site with the exception that the work is done underwater.

Procedures and equipment used for Phase II investigations must be varied accordingly for prehistoric versus historic sites and for differing environmental conditions such as water depth, suspected burial depth within the bottom sediments, type of bottom sediment, and currents. Prehistoric site investigations on the OCS must require taking sediment cores of the bottom and analyzing these cores for the presence of artifacts, midden deposits, and sedimentary and chemical indicators of archaeological deposits. It is not likely, except in low-energy lacustrine or lagoonal

environments, for submerged prehistoric sites to be accessible to divers for hands-on examination. The importance of deep vibra-coring (up to 10-m depth) or deeper core drilling cannot be over-emphasized. Core data provides critical information regarding grain size, sedimentary structures, environmental setting and radiocarbon age. Such information is crucial to the interpretation of geophysical records, to landform assessment, and to paleo-sea level analysis.

Submerged historic sites are frequently accessible to divers (however, not the case on DOCS). SCUBA diving and the use of surface-supplied air are the most common means of investigating such sites. More often than not, shipwreck sites are partially or completely buried in sediment. Locating a buried site under water so that it can be uncovered for examination can generally be accomplished using a combination of magnetometer survey and probing of the bottom. Once a solid object is encountered by probing at the location of a magnetic anomaly, the object may be excavated using a combination of water-induction dredges, air lifts, water jets, and propwash deflectors. The suspected nature of a buried site should be considered when selecting excavation equipment. For example, use of a propwash deflector may not be appropriate on a site believed to contain fragile organic materials. Water depth is another major factor in determining the type of excavation equipment to be used. Propwash deflectors rapidly lose their effectiveness in depths greater than 3-6 m, depending upon the size of the propwash and the power of the engine used, and do not work particularly well in deep sand, as the grains do not stay suspended long enough for currents to carry them from the vicinity of the hole. Dredges and water jets require that water be pumped from the surface down to the divers. As water depth increases, longer hoses must obviously be used which, in turn, increases the amount of drag caused by currents. In even moderate currents, drag can be a serious handicap. The efficiency of air lifts increases with depth. Sites that are buried too deeply may not be accessible without the use of heavy commercial dredges. Excavation on such a scale is usually beyond the budget of archaeological testing projects and would only be advocated if warranted by the nature of the site.

Extensive archaeological investigations have not been conducted by divers at depths exceeding 50 m. Texas A&M University has worked several seasons at a depth of 48 m on a Bronze Age wreck off of the Turkish coast; however, working at such depths greatly increases the risk to non-commercial divers and the amount of bottom-time indicated to be allowable by dive tables is minimal. The maximum depth allowable by U.S. Navy dive tables, with the diver using compressed air, is 91 m and at this depth, no practical work could be expected due to extremely brief dive times and to the effects of nitrogen narcosis. Depths in the study area drop off rapidly near the coast to greater than 50 m, and in the OCS leasing area depths generally exceed 90 m. At depths approaching or exceeding 50 m, alternate means of site investigation should be considered. Alternatives for deep site investigation include the use of helium-oxygen mixtures for divers and/or remotely operated vehicles (ROV) equipped with cameras.

4.2.3 *Mitigation of Impacts to OCS Sites, Phase III*

Archaeological sites discovered on the OCS, if they are eligible for the NRHP, must be avoided by federally permitted or federally funded projects that threaten their destruction or deterioration. If it is not possible to avoid a site, another type of mitigative procedure(s) must be implemented. This would usually entail a Phase III data recovery project. The object of Phase III investigations would be to recover the maximum amount of information from the site that is possible. Data recovery from submerged prehistoric sites would generally involve a program of extracting and analyzing sediment cores. Due to the cost of such a project, this would most likely be combined with Phase II level investigations. Data recovery from an historic wreck site would

likely involve detailed documentation of the site including mapping and removal of artifacts and/or unique portions of the vessel for curation.

4.3 Factors Affecting Detectability

Detectability refers to the ability for state-of-the-art remote-sensing technology to indicate the possible presence of prehistoric and/or historic archaeological sites. A number of factors, both environmental and cultural, affect the detectability of archaeological site locations. These factors vary significantly for prehistoric and historic sites.

4.3.1 Prehistoric Sites

Since remote-sensing surveys do not really detect sites, but rather geologic features likely to be associated with sites, this section is limited to a discussion of factors affecting the detectability of such geologic features. The types of geologic features most likely to be associated with intact prehistoric sites in the study area include paleo-embayments, submerged river valley systems and submerged islands. The lee sides of existing islands also offer major potential for site preservation; however, these are obvious without the use of remote-sensing technology. The presence of natural levees and terraces associated with submerged river valley systems can be inferred and in some instances may be visible in sub-bottom records.

The major environmental factors affecting the detectability of important geologic features were mentioned briefly above. Perhaps the most important factor is sediment composition. Highly organic sediments can attenuate the acoustic signals and may significantly reduce both penetration depth and resolution of sub-bottom data. Organic sediments are frequently associated with low-energy environments such as embayments, sluggish river systems, and abandoned stream channels. Attenuation of acoustic signals by organic sediments may reduce the resolution of important features while indicating the possible presence of those same features. This is not to say that landforms on the scale of stream valleys would not be highly visible in sub-bottom records, rather that the resolution of smaller-order features such as terraces and levees may be decreased.

The detectability of submerged river valley systems and associated smaller features can be improved by running survey lines perpendicular to the expected orientation of drowned channel systems. The most likely orientation of submerged stream systems may not be obvious in a particular locality until some amount of seismic survey has been done in that area. Once sufficient data has accumulated in a particular locality to allow prediction of predominant trends in channel orientation, then survey strategies should be adjusted appropriately for other lease blocks in the vicinity.

4.3.2 Historic Sites

The most important factors affecting the detectability of shipwreck sites is the composition of the vessel and the mass of iron contained in the vessel. Shipwrecks could be classified into three general categories of detectability according to the relative amounts of iron contained in their composition (assuming vessels of the same approximate dimensions): 1) iron- and steel-hulled vessels; 2) wooden-hulled vessels containing steam-, diesel- or gas-powered machinery; and 3) wooden-hulled sailing vessels. Typical anomaly characteristics associated with each of the above categories are known only in general terms. There is a definite need for a database of ground-truthed remote-sensing signatures to provide more of an empirical basis for

characterizing the range of variability within each of these categories. In general terms, the peak amplitude for an iron- or steel-hulled vessel (assuming a sensor-source distance of less than 6 m) could easily be in the range of 1,000 to 10,000 gammas, directly over the top of the vessel (e.g., Hoyt 1990). A wooden-hulled vessel having power machinery might produce a maximum anomaly in the 500 to 2,000 gamma range (e.g., Arnold 1982a; Hoyt et al. 1990). A wooden-hulled vessel without machinery would likely result in a maximum anomaly of considerably less than 1,000 gammas and possibly as small as 25-50 gammas directly over the top of the vessel (e.g., Arnold and Weddle 1978; Gearhart 1988b). Unless the magnetometer sensor passes directly over the top of a vessel, however, the amplitude may be considerably less for each of these vessel categories than suggested by the above ranges. The amplitude of magnetic anomalies decreases (falls off) rapidly with distance (in inverse proportion to the cube of the distance between the source and the sensor). As a result, large wooden-hulled vessels may go completely undetected at distances in excess of 30 to 45 m.

It is obvious from the above discussion that iron- and steel-hulled vessels are much more detectable, using a magnetometer, than are wooden-hulled vessels. Wooden-hulled vessels with power machinery fall somewhere in between these two extremes. Another factor that contributes to the detectability of steel-hulled vessels is their added structural strength. The structural integrity of the hull is likely to remain intact for a longer period of time than would be the case for wooden-hulled vessels, thus increasing their detectability using side-scan sonar.

The proportion of archaeological shipwreck sites fitting into each of the above categories has changed over the course of time. The development of steam-powered vessels was a long process, lasting through most of the eighteenth century, but by the 1880s, they were major competition for America's wooden sailing fleet. Steamships first sailed along the Pacific coast in the late 1840s. In 1847, Congress passed the mail steamship service bill. This act authorized the establishment of a steam trade between New York and California via the Isthmus of Panama.

Although the Panama steam route was a great success, transpacific steam trade was slower to develop. The first steamers to cross the North Pacific were the warships *Mississippi* and *Susquehanna* of Commodore Matthew Perry's squadron after the opening of Japan in 1854. Although a very few merchant steamers made transpacific runs during the 1850s, most did so under power of sail, as there was no coaling stop on the direct route to China from San Francisco (Tate 1986:21-23).

Following the economic slump of the Civil War, Congress passed legislation in 1865 to encourage the development of a transpacific steamship trade with Japan and China. By 1871 the Pacific Mail Steamship Company had six transpacific steamers in service, four on the direct San Francisco to Yokohama route and two providing monthly service between San Francisco and Honolulu (Fairburn 1945:1392-1393).

American shipbuilders had been using iron to a very limited extent as early as 1838 (Fairburn 1945:1401). By 1861, 11 out of a total 264 steamers built in the states (including riverboats which continued to use wood throughout their history) had iron hulls. In 1871, 23 iron-hulled steamers were built in America (out of 302 total), however, Pacific Mail persisted in using wood for their transpacific steamers due to a lack of iron foundries that could build a ship of the proportions considered suitable for transpacific trade. In 1872 Congress authorized new subsidies to encourage the development of iron screw steamers in the transpacific trade. The giant wooden transpacific paddlewheelers last sailed in 1879. Coincidentally, this was the first year that steam tonnage built in the United States exceeded that of merchant sailing vessels. Steam tonnage production in the United States did not pull ahead of sail tonnage for all time until 1885. Five years later, in 1890, the number of casualties occurring to steam vessels on the Pacific coast first caught up with the number for sailing vessels (Figure I-2). The number of casualties for steam

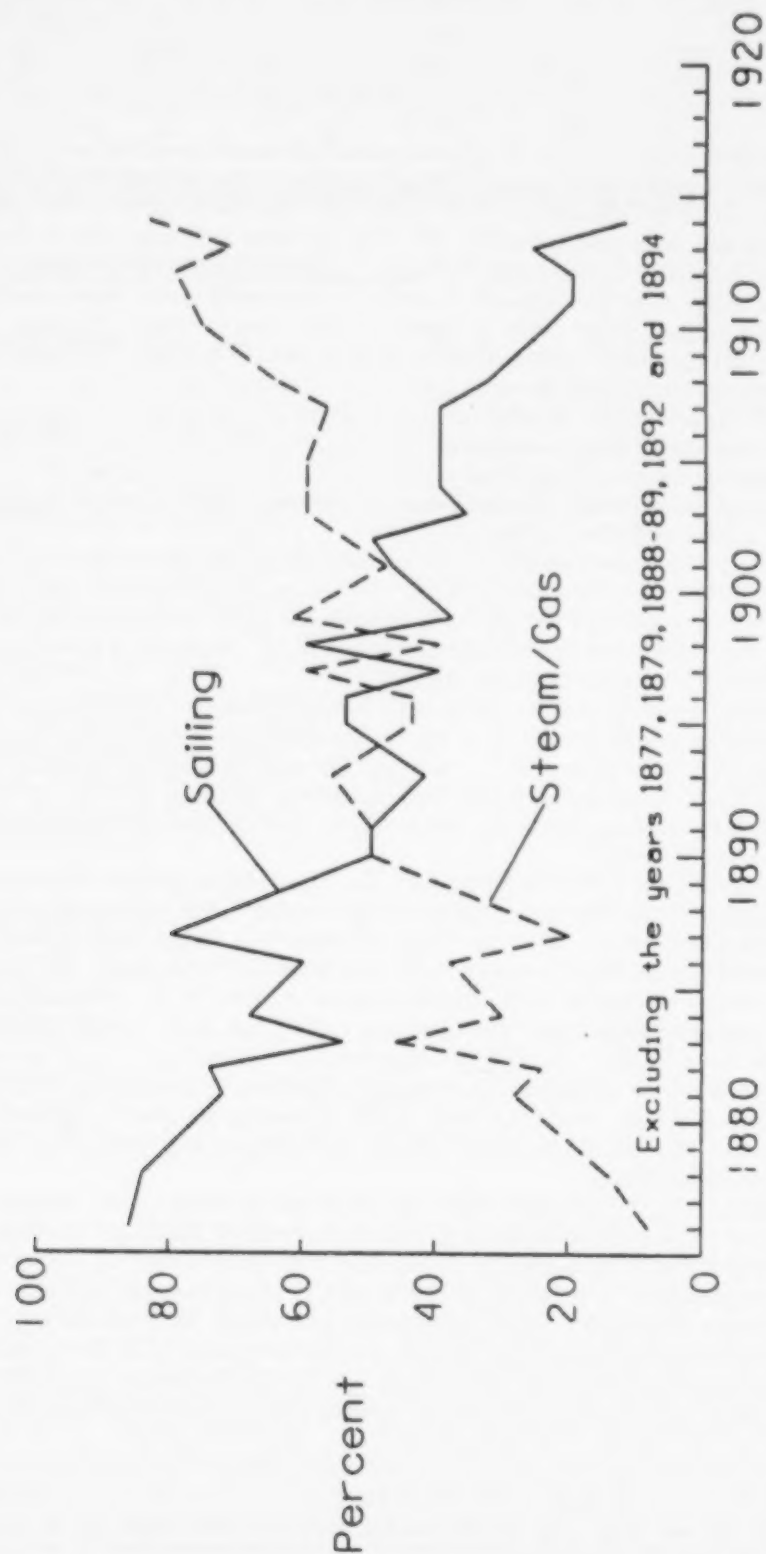


Figure I-2. Average Annual Frequencies (%) of Casualties Involving Sailing Versus Steam/Gas Vessels, 1876-1914.

versus sail stayed relatively even until 1903 when casualties to steamers soared by comparison with sailing vessels which fell off dramatically (U.S. Treasury Department 1876-1914).

The peak of sail tonnage produced in the U.S. occurred in 1855. In that year 1,781 merchant sailing vessels were built, including: 381 ships and barks; 126 brigs; 605 schooners and 669 sloops. Steam tonnage, however, rose steadily throughout the nineteenth century, picking up momentum in the 1850s. Over the course of the century, ocean-going steam vessels evolved from sailing ships having auxiliary steam power to steam vessels having auxiliary sail power. "...until almost the end of the nineteenth century, every steamship was...fully rigged for sail, for no one knew when the engines might break down, or if a storm would delay the ship until its coal supply became exhausted" (Tate 1986:21). By 1910 steam was the undisputed champion of deep-sea trade, as was the steam tug-towing barge combination in coastwise trade. The steam-powered screw remained the dominant source of propulsion up until 1941. Steel was becoming the material of choice for large ocean-going vessels. Twentieth-century passenger liners, warships, freighters and tankers came to be built exclusively of steel.

Figure I-3 illustrates the proportion of shipwrecks from the MMS database which occurred to each major vessel type for the entire historic period. Only the most commonly occurring vessel types are included in Figure I-3. A complete list of vessel types represented in the database for the Pacific coast can be found in Appendix G. Appendix G also indicates the number of unique wreck events within each category.

The most noticeable feature of Figure I-3 is the dominance of schooners over all other vessel types. Approximately 30 percent of all shipwrecks having occurred along the Pacific coast were schooners as opposed to 20 percent for steamers. The high frequency of schooners wrecked along the Pacific coast is reflective of the high proportion of ships wrecked by stranding. Schooners, having been the most commonly used vessel in coastwise trade, should also have been the type most frequently stranded.

Another notable feature of Figure I-3 is the importance of gasoline- and oil-powered (diesel) vessels relative to the frequency of other vessels wrecked. The vast majority of gas- and oil-powered vessels were wrecked during the twentieth century. As a combined class of vessels, gas- and oil-powered account for 15.4 percent of all shipwrecks in the database. By comparison, merchant sailing vessels account for 44.2 percent; steamers account for 19.7 percent; and barges and scows total a combined 5.0 percent. The remaining 15.7 percent of shipwrecks in the database consist of various "other" types of vessels (see Appendix G). Based upon these statistics, the shipwreck population can be subdivided approximately according to the three general levels of detectability described above. Wooden-hulled vessels containing no power machinery should account for at least 44 percent, and probably closer to 55-60 percent, of shipwrecks on the Pacific coast (excluding small watercraft).

Wooden hulls, by far, outnumber any other type of construction material for the period of the study. The vessel loss tables published in *Merchant Vessels of the United States* indicate type of hull material for shipwrecks dating from 1906 until beyond the end of the study period in 1946. According to these tables, 94 percent of U.S. vessel losses in 1906 were wooden-hulled; 4 percent were steel-hulled; and 2 percent were iron-hulled. By 1946, the proportion of wooden-hulled vessels lost had decreased to 70 percent, with the balance of 30 percent being steel-hulled vessels. One can surmise from these figures that the vessel category having the highest degree of detectability (i.e., steel-hulled vessels) comprises the lowest proportion of wreck sites in the study area.

The combined percentage of steel- and iron-hulled wrecks is estimated at 10-15 percent. By the process of elimination, this would mean 25-44 percent of historic wrecks in the database fall into the mid-range level of detectability, being wooden-hulled vessels with power

Percent

I-31

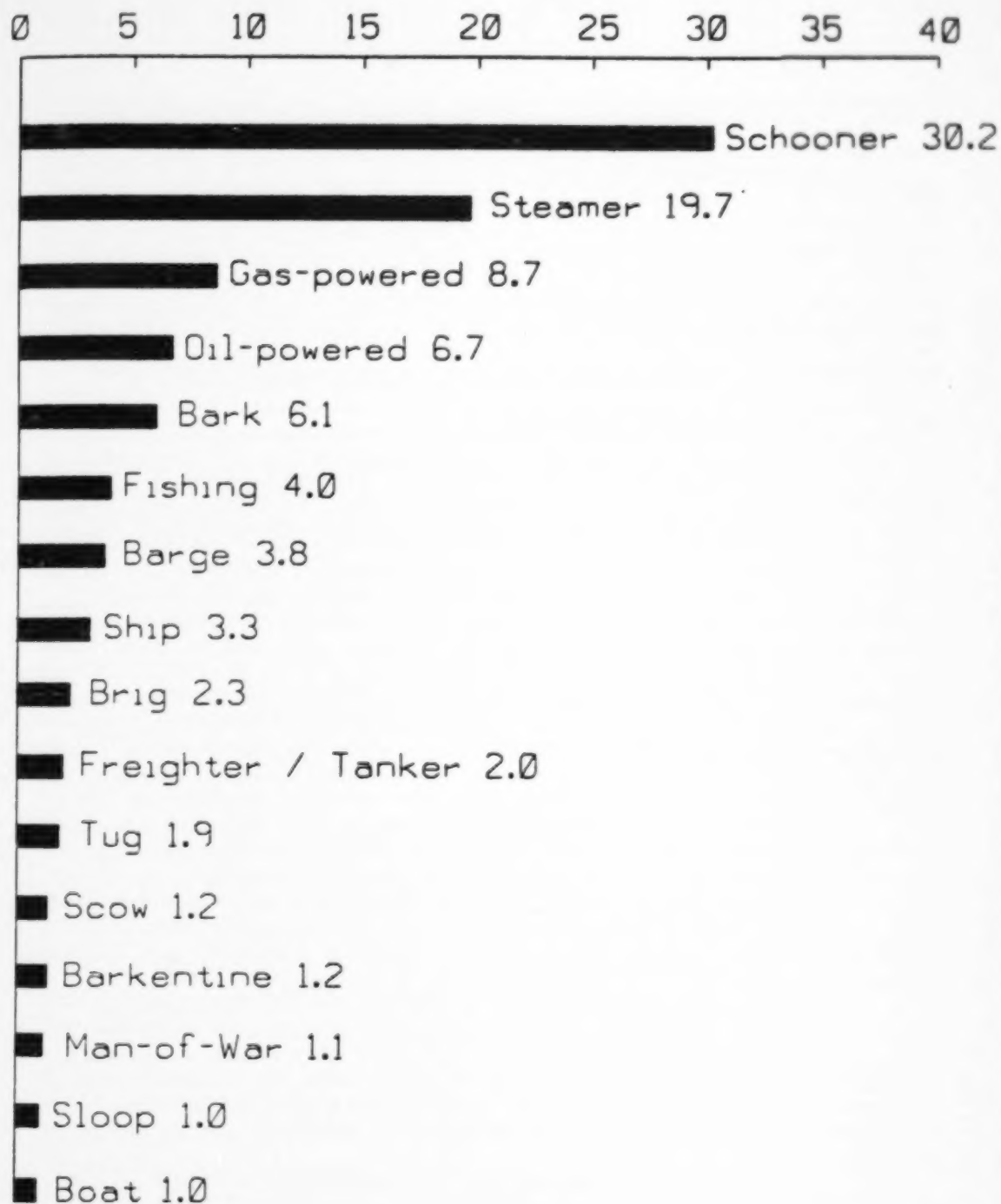


Figure I-3. Relative Frequencies (%) of Shipwrecks by Vessel Type

machinery. Salvage of machinery from nearshore wrecks would likely shift many of the wrecks in this category toward the low end of the detectability range.

In summary, a majority of historic shipwrecks in the database are in the least-detectable category using state-of-the-art remote-sensing techniques. Furthermore, the proportion of wrecks falling into this category is significantly greater for the nineteenth century than for the twentieth century. The detectability of heavily armed early sailing vessels, for example, Manila galleons or early fur trade vessels, could be expected to be slightly greater than unarmed merchant sailing vessels of comparable size. Small watercraft, which are poorly represented in the database, would be significantly less detectable than the vast majority of wooden-hulled merchant sailing vessels. The relatively low level of detectability for most shipwrecks in the database argues for careful consideration of survey line-spacing and cautious assessment of remote-sensing data.

4.4 Current MMS CRM Requirements

The MMS (then BLM) became involved with archaeological resource protection on the OCS in December 1973 when, for the first time, cultural resource surveys were required through a lease stipulation (Ruppe' 1980). A year and a half later, the USGS began requiring geophysical surveys to locate shallow geological hazards before permitting oil and gas exploration or development in lease blocks. Nearly the same instrumentation was required for both types of surveys; therefore, they soon were combined and have been conducted simultaneously since. The reasons for the two types of surveys remain quite different, however. Geohazard surveys are designed to locate dangerous geologic features, such as shallow gas pockets, that might pose a hazard to drilling or pipeline operations. These are required on all lease blocks prior to exploration or development. Cultural resource surveys originally were required for all lease blocks; however, this requirement was soon revised to include only those lease blocks likely to contain archaeological sites, either prehistoric or historic, preserved in or on the bottom sediments. Today, OCS archaeological survey requirements constitute only a small percentage of the cost to the mineral industry for conducting the combined geohazard/archaeological surveys (Ruppe' 1980).

Soon after the OCS archaeological program was instituted, the realization was made that it was not practical to require a survey of every lease block, nor was it necessarily desirable since not all areas of the OCS have an equal potential for containing archaeological sites. In order to provide an empirical basis for deciding which lease blocks would require an archaeological survey, archaeological baseline studies, similar to this report, were completed for the various OCS regions within the BLM, beginning with the Gulf of Mexico Region (Gagliano et al. 1977) and the southern California portion of the Pacific Region (Science Applications, Inc., 1977).

With the completion of the first regional baseline studies of OCS archaeology in 1977, federal archaeological requirements on the OCS gradually became more streamlined and systematic. Current practices require that MMS staff review the prehistoric and historic site potential for each lease sale based upon the regional baseline studies. This process is part of the overall environmental review for each lease sale and is designed to determine which lease blocks will require archaeological investigations and the submittal of an archaeological resource report by lessees.

If the MMS staff determines that there is a potential for regulated OCS activities to affect an archaeological resource, an archaeological remote-sensing survey will be required of the specific lease block(s) in question. This survey is conducted concurrently with the geohazards survey. The lessee is responsible for acquiring the services of a qualified marine survey archaeologist to interpret and assess the remote-sensing data, with regard to potential

archaeological resources, and to write an acceptable archaeological report of the survey results for submission to and review by MMS.

The level of archaeological survey required on individual lease blocks is determined by the type of archaeological resource(s) potentially affected by OCS activities. Prehistoric remote-sensing studies typically have required the use of a seismic sub-bottom profiler and a side-scan sonar. The object of these surveys is to locate paleo-landforms, submerged by the Holocene sea level rise, that have a high likelihood of containing prehistoric sites. The most "visible" examples of such landforms are drowned river valleys appearing in seismic profiles of the sub-bottom. Historic archaeological survey requirements (primarily designed for detecting the remains of shipwrecks) dictate the addition of a magnetometer for the detection of iron elements commonly associated with wreck sites.

Current minimum archaeological requirements in effect for the Pacific OCS are specified in Notice to Lessees (NTL) 77-3, reproduced in Appendix C. NTL 77-3 was issued on 1 March 1977 and, although currently in effect, is under revision by MMS. At present, the Pacific OCS Region of MMS requires a maximum survey line-spacing of 150 m for both historic and prehistoric remote-sensing surveys. The Gulf of Mexico Region requires a 300-m spacing for prehistoric and geohazard surveys and a 150-m spacing for historic surveys. Consideration is currently being given toward reducing the historic survey line-spacing to 50 m for the Gulf of Mexico.

5.0 RECOMMENDATIONS

Archaeological recommendations for the predictive zones proposed by this study do not differ significantly in type from current MMS archaeological requirements as specified in NTL 77-3. The principal survey instruments remain the magnetometer, the side-scan sonar and the sub-bottom profiler. There are some significant differences, however, in the level to which these technologies would be applied under the current NTL requirements versus under the archaeological recommendations suggested here for the predictive zones delineated in this study. These differences have been highlighted below in a discussion of NTL 77-3 and of suggested improvements in the wording of future NTLs. Following this discussion, specific archaeological recommendations are made for each archaeological predictive zone.

5.1 Recommended Revisions to NTL 77-3

Our knowledge of marine archaeology has changed considerably since 1977 when NTL 77-3 was issued. The need for revision of MMS OCS archaeological survey requirements is perhaps greater for the Pacific Region than for any other region of MMS, as more recent NTLs are in effect for other parts of the OCS. Substantial revisions to NTL 77-3 are being considered by MMS; however, the revised NTL has not been finalized as of the date of this writing. There is no doubt that, when finalized, the Pacific Region NTL will be more specific than NTL 77-3 regarding archaeological survey requirements. Nevertheless, there are a few key criticisms that have been repeatedly leveled at the MMS OCS archaeological program in general that have yet to be incorporated into any NTL.

The major issues needing to be addressed in NTL revisions have been known and debated for several years within the archaeological community. Numerous meetings have been held specifically to discuss the goals and needs of the OCS archaeology program. The results of these discussions have been summarized in a number of publications and archaeological symposia (e.g., Ruppe' 1980; MMS 1989; Aten 1989). The items most desperately in need of revision, in the author's opinion, are summarized below. Credit is given to the many individuals who first proposed these suggestions.

Line-spacing. Line-spacing refers to the horizontal distance between survey transects. There is a direct correlation between line-spacing and data resolution from marine remote-sensing surveys. The minimum line-spacing for OCS historic archaeological surveys has been specified as 150 m in the various NTLs issued by BLM/MMS. Archaeologists have argued for some time that this interval was inadequate for marine magnetometer surveys on the grounds that historic shipwreck sites could go completely undetected (Clausen and Arnold 1975; Arnold 1982b; Saltus 1986). One-hundred and fifty meters is well within the range of side-scan sonar and is an acceptable interval for sub-bottom seismic profiles when looking for large geomorphic features such as stream valleys. Applying this same line-spacing requirement to magnetometer surveys, however, results in, at best, a 25 percent survey coverage for wooden- or composite-hulled vessels (Saltus 1986).

The most commonly used criterion for identifying potential wreck sites is the presence of magnetic anomalies at adjacent points on two or more neighboring survey lines. Various estimates have been made by archaeologists for the minimum spacing necessary on magnetometer surveys to ensure detection on multiple lines. These estimates range from 45 m (Arnold 1976) to 30 m (Smith et al. 1987). The minimum spacing that would allow detection of a wreck such as the Spanish nao *San Esteban* on more than one survey line is estimated at 45 m (Arnold and Weddle 1978:197). Saltus (personal communication with R.L. Gearhart, June 17, 1988) emphasizes that

smaller, but not necessarily less significant, vessels may appear on only one line or may go completely undetected using a 45-m line-spacing. Arnold (1982a) illustrated magnetometer strip charts from the survey of a twentieth-century wooden-hulled shrimp trawler which was detected on only one line using a 45-m line-spacing. Smaller wreck sites or wreck sites containing less ferrous material than the *San Esteban* may appear on only a single survey line or could go completely undetected at intervals even closer than 45 m. Smith et al. (1987) demonstrated that the remains of a Civil War-period anti-torpedo raft on Mustang Island, Texas, might appear on only one survey transect using a line-spacing of 30 m.

The current requirement of 150 m for the line-spacing on OCS historic magnetometer surveys provides incomplete survey coverage of, at best, 25 percent of each lease block surveyed for wooden- and composite-hulled vessels (Saltus 1986; Weymouth 1986). This means that even in a lease block known to contain an historic shipwreck, there is only about one chance in four that the wreck anomaly would be detected on more than one survey line. On the other hand, there are about three chances in four that such a site would go undiscovered and that bottom-disturbing activities would be approved for an area of the OCS containing a known historic resource without further regard for that site. To paraphrase a familiar cliché, such sites fall through the cracks by falling between the lines. Once cultural resource clearance is given for a lease block that clearance extends to all future operations within that particular lease block; therefore, it is imperative that adequate surveys be conducted. Although the issue has not been settled as to what line-spacing would constitute a 100-percent survey, the authors are recommending the adoption of a 40-m line-spacing requirement for magnetometer surveys in areas having a high probability for the occurrence of historic archaeological sites. This figure is offered as a compromise between 30 and 45 m, although it may not result in a 100 percent survey in all instances. It is also emphasized that detection of adjacent anomalies on multiple lines should not be the sole criterion for determining which anomalies are significant and therefore worthy of further investigation.

The line-spacing currently required in the Pacific Region for OCS prehistoric (seismic profile and side-scan sonar) surveys is 150 m with crossing tie-lines at 1,000-m intervals (400-m tie-lines for exploratory drilling). This coverage seems adequate for locating culturally sensitive submerged and buried landforms. In fact, the Gulf of Mexico Region requires only a 300-m interval between lines. The depth of penetration required on all sub-bottom surveys should be sufficient to reach the Pleistocene/Holocene unconformity, as determined from the Holocene Sediment Isopach Maps in Volume V and/or from seismic profiles recorded in adjacent or nearby lease blocks. Resolution of sub-bottom records should be better than 1 m. For historic site side-scan sonar surveys, a maximum line-spacing of 160 m is recommended (every fifth line if surveying with the magnetometer at a 40-m line-spacing) with a maximum range setting of 100 m and a resolution of better than 1 m.

Sample Surveys. Opinion is divided on the question of sample surveys. Ruppe' (1980:10), for example, has argued that since sampling is an accepted and justifiable research strategy on land, there is no reason to reject its use on the OCS. This is a valid point; however, sampling is not used on the continent with total disregard for probability of site occurrence. Once reasonable probabilities are established for onshore site distributions, sampling is often stratified to provide a higher density sample in areas having a higher site probability. In terrestrial areas that will experience complete destruction of the site population (e.g., open pit mining areas) State Historic Preservation Officers (SHPO) often require 100-percent surveys. The underwater equivalent to open pit mines is sand and shell borrow areas and in the future, may include mining of heavy minerals on the OCS.

In a recent symposium presentation on the subject of MMS OCS archaeological surveys, Lawrence Aten of NPS made a valid point regarding sampling on the OCS. "Although it

is not practical to expect high-resolution coverage [referring here to line-spacing] of all leases, it is justifiable in specific instances when our expectations are high" (Aten 1989). The definition of "high" expectations (i.e., probability) is another subject for debate. As argued below, this definition should not be inflexible. It should be subject to reassessment on the basis of regional mapping of survey results and updating of baseline archaeological studies.

Interpretation of Survey Data. It has been argued by the mineral industry that the OCS archaeology program has been less than successful in locating archaeological sites on the OCS and that it should therefore be discontinued or curtailed (Ruppe' 1980:5). A very large number of unidentified magnetic anomalies have been located by archaeological surveys on the OCS, yet few have been investigated. Most shipwrecks that have been identified from these surveys have been identified on the basis of side-scan sonar records. Likewise there have been very few prehistoric sites located on the OCS by comparison with the number of lease blocks that have been surveyed for prehistoric sites.

While it is true that few archaeological sites have been positively identified as a direct result of the OCS archaeological program, it is not accurate to say that the program has been unsuccessful. Nor is it entirely accurate to say that OCS archaeological surveys have not located many archaeological sites. Many of the magnetic anomalies located by these surveys are undoubtedly associated with historic archaeological sites, both shipwreck sites and sites of lost or jettisoned cargo. While the proportion of anomalies associated with archaeological sites cannot be known without conducting extensive ground-truthing studies, it seems safe to assume that where the density of magnetic anomalies increases, the density of historic sites also increases. Fewer prehistoric sites have been discovered than historic sites because ground-truthing is always necessary to identify prehistoric sites. However, a large number of submerged and buried landforms that are likely to mark the locations of preserved prehistoric sites have been located as a direct result of MMS' OCS archaeology program. A few of these have been tested with positive results through coring and diver investigations (Stright 1990).

Several suggestions have been offered over the years for the improvement of our remote-sensing interpretive abilities. For example, Ruppe' (1980) emphasized increased cooperation between geophysicists and marine survey archaeologists to improve the quality of interpretations. The most commonly proposed means of improving the present situation is through a combination of ground-truthing studies and the development of a remote-sensing signature catalog or database (e.g., Ruppe' 1980; Arnold 1982a, 1982b; Aten 1989). Ruppe' succinctly characterized the problem as follows:

There are a number of important issues that affect the success of the OCS survey program. Probably the most important is the need to develop a ground truth testing program to learn the causes of the anomalies seen on the strip charts. It will be necessary to establish a catalog of characteristic signatures to assist the marine survey archaeologists in their analysis of the records (Ruppe' 1980:25).

Underwater archaeology, whether devoted to drowned terrestrial sites or shipwrecks, suffers from a lack of credibility. The single greatest shortcoming is our inability to identify the nature of the material phenomena that are detected as anomalies on strip charts produced by the remote sensing instruments (Ruppe' 1980:25).

The reason for the uncertainty is the lack of investigation, or ground truth testing, into the causes of the anomalous signals... A systematic campaign of ground truth testing will, over a period of time, produce evidence that will permit us to develop a catalog of signals and their original, causative sources (Ruppe' 1980:26).

Recently MMS sponsored a ground-truthing study in the Gulf of Mexico for the purpose of updating the shipwreck portion of Gagliano et al.'s (1977) Gulf of Mexico baseline study (Garrison et al. 1989). One of the main objectives of Garrison et al.'s study was to determine the limitations of current survey methods for discriminating between submerged historic sites and modern ferrous debris. This problem was approached by ground-truthing a sample of magnetic anomalies. A major conclusion was that the 150-m line-spacing was inadequate to allow differentiation between shipwrecks and other assorted ferrous objects commonly found on the OCS. In order to improve upon this situation, Garrison et al. (1989) recommended the adoption of a 50-m line-spacing in areas having a high probability for containing historic shipwrecks. Even using a 50-m spacing, however, the potential for discriminating between historic shipwreck sites and modern debris on the basis of magnetic survey data is extremely limited. The author, for example, recently conducted a marine survey off of the coast of Florida using a 45-m line-spacing (Gearhart, 1988) and could not justify the exclusion from further investigation of any anomalies with an intensity of greater than 4 gammas and a duration of greater than 4 seconds (at an average survey speed of 5 knots). Nevertheless, a 50-m spacing increases the survey coverage to a more acceptable level than the currently required 150-m spacing.

An anomaly signature database or catalog based upon ground-truthing studies would undoubtedly be the most effective means of developing our interpretive abilities to the point of discriminating between shipwrecks and modern ferrous debris. This idea has been proposed many times and the beginnings of such an anomaly catalog, containing magnetometer strip charts for a number of anomalies that have been ground-truthed, was assembled by Arnold (1982a).

At least five alternatives exist for gaining the needed high-resolution remote-sensing survey data on ground-truthed anomalies. First, ground-truthing studies could be financed through public research grants. Second, schools offering graduate coursework in maritime archaeology and/or archaeological remote sensing could encourage such studies as dissertation topics. Third, government agencies such as MMS could sponsor the needed studies. The recent MMS-sponsored ground-truthing study by Garrison et al. (1989) was a start in the right direction toward remedying the lack of well-documented anomaly sources. Fourth, marine survey archaeologists could independently conduct experiments in magnetic survey and present the results in a series of symposia (e.g., Saltus 1980). Finally, the required resolution of remote-sensing data (i.e., closer line-spacing and tighter positioning control) could be increased on contracted marine archaeological studies whenever ground-truthing is required.

The authors have suggested adoption of a 40-m interval for surveying those lease blocks where a 100-percent magnetometer survey coverage is desired. Using a 40-m spacing, the vast majority of shipwrecks should be detectable, although discrimination of wreck anomalies from non-wreck anomalies may have a relatively low success rate. A wider line-spacing would be appropriate for lease blocks having a lower potential for the occurrence of historic archaeological sites where some level of sampling appears justified.

The importance of the magnetic survey requirement to the OCS archaeology program cannot be overemphasized. As discussed above, the goal of the program is to avoid sites, rather than to identify and extensively investigate them. In order to avoid sites we must locate them or at least identify locations where they are likely to occur. Unless anomaly sources are visually

identified either by divers or by remote video camera, the only way to insure avoidance of historic sites is to avoid magnetic anomalies. By locating and avoiding magnetic anomalies, we are very definitely locating and avoiding historic archaeological sites. The present low rate of success in distinguishing anomalies associated with shipwreck sites from those caused by non-significant iron debris should not detract from the usefulness of the magnetometer survey in protecting historic archaeological sites on the OCS.

Regional mapping/updating of baseline studies. Another valid criticism of the OCS archaeology program has been that there is very little feedback of information from the results of individual lease block surveys to the regional picture of archaeology on the OCS. Aten (1989) suggests that more emphasis be given toward updating regional baseline studies, such as this one, using remote-sensing survey data and the results of submerged site investigations. "Geomorphic reconstruction, magnetic anomaly interpretation, and evaluation of the probability of cultural site occurrence is difficult for surveyors to do on a lease by lease basis without a larger frame of reference... MMS should explore ways to compile the results of lease block surveys and miscellaneous other sources such as core studies into composite maps" (Aten 1989).

The authors could not agree more with this idea. Baseline studies should be just that, baselines of information used to guide the effective protection of cultural resources on the OCS. As our knowledge of OCS geology and archaeological site distribution grows, the nature of the baseline changes. Unless the information contained in these baseline documents is continuously updated, especially the information contained on the study area maps, these management tools will quickly become obsolete. Baseline studies should be viewed as a starting point for research and management rather than as the final word, the latter which they certainly are not. The only way to keep current in our assessment of "high expectation" areas (from Aten 1989) is by updating baseline studies and refining predictive zone maps.

MMS currently updates baseline studies on a regional scale prior to major lease block sales, as specified in their Manual for Archaeological Resource Protection. The nature of these updates is on a different scale than that proposed by Aten (1989) or by EH&A in this study. Presently there is no mechanism within MMS for the compilation of lease block survey data on large-scale maps of the OCS. This is exactly what we are recommending be undertaken. To do so for OCS regions, such as the Gulf of Mexico where incredible backlogs of survey data exist, would be a formidable, though not impossible, undertaking; however, to do so for the Pacific Region where there is no data backlog, such a mapping effort would be easy and inexpensive. The benefits could be enormous.

The following scenario illustrates the importance of updating regional base maps for refining predictive models and research designs. Suppose that a regional baseline study had been conducted of a large terrestrial area. It was concluded by the study that upland areas having semi-permanent water supplies have a high probability for containing prehistoric sites. To test this hypothesis, you plan to excavate 1,000 shovel tests, evenly distributed across a 100-acre upland area adjacent a semi-permanent water supply. After excavating the first 500 shovel tests on an evenly spaced grid, you have found only two small flint chips which are questionably of cultural origin. At this point you would likely (and justifiably so) consider modifying your research design. You might also conclude that the previous researcher's predictive model was overly simplistic and look for other variables which might be better predictors of prehistoric site location. The OCS correlary of this scenario is easy to imagine. Suppose a large number of lease blocks were surveyed in an area considered to have a high probability for containing historic shipwrecks with the result that very few magnetic anomalies and side-scan targets were located. The natural conclusion would be that fewer shipwrecks are present in the area than originally suspected. If a preponderance of lease block surveys suggests the need to modify the predictive zones suggested in this baseline study,

then by all means they should be modified, but such a decision cannot be made in the absence of regional mapping.

Another strong argument for regional mapping of OCS archaeological survey results is that the interpretation of individual lease block surveys would not occur in isolation. The results of surveys from adjacent lease blocks and from lease blocks occurring in similar settings (e.g., in sealanes or offshore of harbor mouths) could be easily compared by the marine survey archaeologists responsible for interpreting the data. Submerged and buried riverine features noticed in individual lease blocks could be correlated with regional drainage patterns as they are pieced together from adjoining survey results.

The locations of all magnetic anomalies and side-scan sonar targets, unless positively identified as other than historic archaeological sites, should be mapped on a regional scale as lease block surveys are completed. Updating of the baseline study maps in this manner would provide a better indication as to the distribution of historic archaeological sites in the offshore area than is possible at the present time. As remote-sensing data accumulates, the Historic Site Predictive Zone Maps should be refined to indicate locations both of unexplained magnetic anomalies and side-scan signatures and of verified archaeological sites. This information could then be used for refinement of the predictive models. It is anticipated that the net result of this effort would be a reduction in the number of lease blocks requiring a magnetometer survey for historic sites. This offers perhaps the greatest potential for cost savings to industry of any recommendation made here, since 100-percent survey coverage with the magnetometer requires a significantly closer line-spacing than is required for the mandatory geohazard surveys.

Regional mapping of sub-bottom geologic features should be mandatory for all lease blocks regardless of their potential for prehistoric sites. As geophysical survey data accumulates for lease blocks within the study area, this information should be added to the appropriate submerged paleo-landform maps, thereby refining our knowledge of where submerged riverine systems may occur. This information could then be used to refine the Prehistoric Site Predictive Zone Maps. The result of this effort would be a more precise knowledge of which areas constitute high-probability zones for the occurrence of prehistoric sites. Aten (1989) also pointed out that regional mapping of sub-bottom geologic features would facilitate interagency/interdisciplinary paleo-environmental studies since prehistoric sites tend to be concentrated sources of environmental data in a dateable context. One effect of regional mapping should be a reduction in the number of lease blocks requiring both archaeological assessment reports and mitigation of potential impacts to prehistoric sites.

Updating of the study area maps could be done most efficiently on a computer-assisted-design (CAD) mapping system, as opposed to updating maps on small-scale (1:250,000) mylar or paper copies, since all of the data overlays for Volume V were produced using a CAD system. Lease block maps showing the locations of magnetic anomalies, side-scan targets and submerged geologic features could quickly be digitized as new data layers preserving the resolution of the original survey data. Alternately, if map illustrations for each geophysical or archaeological report were produced on a compatible CAD system, these graphics files could easily be copied to the appropriate geographic coordinates of the Volume V maps as data overlays at no significant cost to either industry or MMS.

An obvious advantage to CAD-based regional mapping is the fact that any or all data overlays can be viewed and/or plotted at the same time and at any scale. For example, all drowned riverine features could be viewed on-screen (or in a plot) for the area offshore of the Columbia River simultaneously with the prehistoric site predictive zones, onshore prehistoric sites, and Holocene isopachs, all of which would be pertinent to the potential of the area to contain preserved prehistoric sites. A plot of the above scene could be made available to marine survey

archaeologists responsible for writing archaeological assessments of individual lease blocks in this vicinity. One result of such a program would undoubtedly be an improved quality of OCS archaeological reports and survey interpretations.

Another advantage to CAD-based regional mapping is that such a system would allow a fairly inexpensive transition to the use of a Geographic Information System (GIS). Although not called for under the current project, GIS is increasingly being relied upon for projects such as this one involving large-scale map databases. By combining the intelligence of the prehistoric and historic site databases with both the geographic information contained on the project maps and the geophysical data from future lease block surveys, a GIS database could ultimately be built that would allow data queries of a scale and complexity far beyond the scope of the current project. The primary benefits of such a database would be refinement of the predictive models through formulation and testing of archaeological research questions with a resulting net savings to the mineral industry on the amount of money spent on OCS archaeology.

Another benefit, secondary to archaeological goals, which MMS may wish to capitalize upon is the use of the same GIS database for information from other scientific disciplines pertinent to the management of OCS mineral resources. For example, data regarding marine biology, physical oceanography, deep core geology, seismology, pipeline and cable routes, ocean disposal areas, oil and gas well locations, commercial shipping lanes, fishing grounds, and any number of other types of information could be added to such a database. The benefits of such a system will be obvious to those familiar with GIS and are not discussed further here.

Quality Control. The quality of OCS archaeological surveys and survey reports has often been cited as a major problem in all of the MMS OCS regions (e.g., Ruppe' 1980; Arnold 1982b; Aten 1989). Ruppe' suggested one reason for this fact being that NTL guidelines have not been explicit enough regarding MMS requirements. Ruppe' (1980:21) noticed a lack of professionalism by many of the marine survey archaeologists who were writing up OCS surveys. He also noted a problem with inadequate geophysical interpretations in survey reports due to "marine survey archaeologists" having insufficient geophysical experience or geological background and due to excessively noisy survey data. Fortunately, the situation has improved considerably since Ruppe' wrote his report in 1980.

Suggestions for improvement of OCS archaeological reports have ranged from some form of peer review (Aten 1978; cited in Ruppe' 1980) to requiring that reports be published by the National Technical Information Service (NTIS) (Ruppe' 1980; Arnold 1982b). Ruppe' also suggested requiring that geophysicists and marine survey archaeologists collaborate more on the interpretation of survey data and that professional papers be presented on the survey results at archaeological meetings. Arnold (1982b) supported requiring that OCS archaeological reports be submitted to SHPO offices for review by State Marine Archaeologists and suggests that the original geophysical instrument strip charts be permanently curated as is required for archaeological records such as field notes and photographs on terrestrial projects. Curation of geophysical survey data in a digital form compatible with a GIS system, may prove a more practical solution due to the incredible volume of data involved.

It is imperative that the revision of NTL 77-3 contain more specific language regarding the expectations and technical requirements of the OCS archaeological surveys and survey reports. Once concisely worded requirements are in place, it will be up to the archaeological staff of MMS to enforce these requirements, refusing acceptance of any survey reports and/or survey data that does not meet them. A system of peer review would undoubtedly encourage marine survey archaeologists to write higher quality reports. Rather than conducting a peer review of all reports, perhaps they could be selected randomly, blindly reviewed (without the reviewers knowing the authors' names), then the reports (with authors' names included) and the corresponding reviews

published in an annual volume by NTIS. Review should be open to any qualified individual. In this way, it would be in the interest of those archaeologists most interested in maintaining high standards to volunteer as reviewers. Permanent curation of strip charts, computerized geophysical and positioning data, and deck logs is also recommended. The quality of archaeological interpretations could be improved by implementing the suggestions discussed above regarding reduction of line-spacing, development of a remote-sensing database, and regional mapping of individual lease block survey results using either a CAD or GIS mapping system.

Recommended changes specific to NTL 77-3. NTL 77-3 applies only to exploratory drilling in less than 394 feet (120 m) of water. It needs to apply to all mineral activities regulated by MMS on the OCS. This depth corresponds approximately with the lowest sea level during the last stage of the late Pleistocene, thus prehistoric sites are not expected at greater depths. This does not account, however, for the possibility that historic shipwrecks may be detected in deeper water on side-scan sonar charts when conducting geohazard surveys. A "chance finds" clause is included in the archaeological lease stipulation attached to every OCS lease. This clause requires lease operators to notify MMS if an archaeological resource is discovered during operations on a lease. This would include instances where something was discovered as a result of a geohazards survey. In such cases, since the archaeological survey and report requirements would not have been invoked, discovery of potential sites depends upon the geophysicist responsible for reviewing the survey data.

NTL 77-3 states that side-scan sonar, fathometer and sub-bottom profiler records from shallow drilling hazards surveys will be acceptable if coverage is adequate. The term "adequate" implies meeting the archaeological survey line-spacing requirements, although this is not clearly stated in NTL 77-3. Specific figures should also be specified for maximum height of the magnetometer sensor above the bottom (6 m), acceptable noise limits in the magnetic data (e.g., 4 gammas peak to peak), the required sample interval for the magnetometer (the magnetometer should be set to cycle at least once per second), and an appropriate range for survey vessel speed (4-6 knots is recommended).

Positioning accuracy of plus or minus 50 feet (15.25 m) at a distance of 200 miles (322 km) from shore is currently required for OCS remote-sensing surveys in the Pacific Region. Positioning technology has improved significantly since 1977. This should be reflected in the revised NTL. Positioning accuracy of 5 m or less should be required for all surveys.

"When anomalies that will be affected by OCS operations cannot be explained by the geophysicist using available information, additional survey data and/or appraisal by a qualified marine archaeologist may be required" (NTL 77-3). Using even a 40-m line-spacing, as recommended above, it cannot be expected that magnetic anomalies be "explained", if this implies identifying their sources, without sending divers or video cameras to the bottom to investigate. All magnetic anomalies that cannot be explained should be avoided by bottom-disturbing activities. If they cannot be avoided, then appraisal, using divers or remotely operated video cameras, by a qualified marine archaeologist, by all means, should be required. Even though all anomalies should be avoided, the marine survey archaeologist should make every effort to prioritize anomalies in the survey report according to the likelihood that each may be associated with an historic archaeological site. The only exceptions to anomalies that should be avoided are single-reading noise spikes, and anomalies caused by passage near other vessels or buoys. NTL 77-3 should be reworded to require appraisal by a qualified marine archaeologist in all cases where anomalies cannot be either explained or avoided.

Under NTL 77-3, when an area has been determined to have cultural significance by an appropriate agency and the minimum survey indicates a site(s) of potential significance in the area, the operator of the affected federal oil and gas lease(s) has three options: 1) ensure the

site(s)' protection through operational procedures; 2) avoid the site(s) by adjusting the location of bottom-disturbing activities; or 3) perform additional survey to define the site(s)' significance and/or present an appraisal by a qualified marine archaeologist. As with most of the wording in NTL 77-3, the wording regarding mitigation options is very non-explicit. Acceptable operational procedures should be described. Minimum distances for avoidance of potential archaeological sites should be specified. Requirements for additional in-site survey should be spelled out. Additional survey and visual appraisal (ground-truthing) of the anomaly source(s) by a qualified marine archaeologist should both be required. The NTL should provide for the nomination of archaeological sites to the NRHP in the event that ground-truthing demonstrates their potential eligibility.

5.2 Archaeological Recommendations Specific to the Proposed Predictive Zones

The predictive zones formulated to describe expected prehistoric and historic site distributions have been summarized above in sections 3.2.3 and 3.3.3, respectively, and in the appropriate technical volumes. An attempt has been made to accurately reflect relative archaeological site potential by the structure of the predictive zone maps. The number of predictive levels/zones illustrated on these maps (Volume V) reflect the fact that numerous factors were considered when formulating these zones. As a result, considerably more zones have been suggested than the traditional three zones representing high, medium and low probability. The number of unique archaeological recommendations suggested here, however, is significantly more limited than the number of predictive zones. To suggest a unique archaeological recommendation for each predictive zone would be placing more confidence in the possible realism of these zones than is warranted by the present level of our archaeological knowledge for the study region. The complexity of the zones as mapped is intended more to suggest working hypotheses for future research than to represent the nature of the universe as we know it.

We cannot claim that the predictive zones are refined and correct. We only claim that they seem to make sense based upon what we know now. If the study maps are updated systematically with remote-sensing data at the level of the individual lease block, it is expected that both the predictive zones and the manner in which archaeological recommendations are applied to these zones will warrant significant revisions within just a few years of having initiated lease block surveys in the study region. In fact, if both the prehistoric and historic predictive zones have not been significantly revised within the first ten years of conducting lease block surveys in the study region, one would have to conclude that there had been a drastic inadequacy in the amount of information feedback from field studies and a general disregard for the scientific method.

5.2.1 *Prehistoric*

Archaeological survey (Phase I investigations) for prehistoric sites is recommended for all areas that have been delineated as potentially containing sensitive landforms, that is, designated with a landform code of c, d, or e (e.g., 1c, 1d, 1e... 5c, 5d, and 5e) on the Prehistoric Site Predictive Zone Maps Volume V. These landforms, including paleoembayments (c), submerged river valley systems, (d) and submerged islands (e), have been discussed in Volume II regarding their distributions and in Volume III regarding their potential for intact prehistoric sites to survive a sea level rise in such settings. The same level of survey is recommended for all of these zones, entailing the use of a sub-bottom profiler, side-scan sonar and recording fathometer, the same instruments required for geohazard surveys.

Line-spacing under normal conditions should not exceed 300 m with crossing tie-lines at a 900-m interval in predictive zones designated c, d, or e. When specific lease blocks are known, from survey results in nearby or adjacent lease blocks, to have a very high probability of containing sensitive landforms, a 150-m maximum line-spacing is recommended with crossing tielines at 450-m intervals. Vessel speed should not exceed 6 knots. The seismic profiler should provide penetration to the depth of the Pleistocene/Holocene unconformity, as determined from the Holocene Sediment Isopach Maps in Volume V and/or sub-bottom profiles or sediment cores from adjacent or nearby lease blocks, with a resolution of better than 1 m. Side-scan sonar tow depth should be sufficient to provide 100-percent coverage, with a minimum coverage overlap of 20 percent, and a resolution of better than 1 m. Automatic correction for slant range and vessel speed should be required. Range should not, however, exceed 100 m at a 150-m line-spacing, nor 200 m at a 300-m line-spacing.

Positioning of the survey vessel should utilize the most accurate method usable in a particular geographic setting. In other words, if it is possible to use a laser- or microwave-based range-azimuth system, then this should be used to the exclusion of other options. Likewise, if a microwave-based range-range system can be used, then this should be done to the exclusion of a satellite-based system. Satellite navigation is currently the least accurate option available. It is anticipated that the majority of OCS surveys would require satellite navigation due to their distance from shore. Even so, it should be possible to achieve an accuracy of 7 m or less using satellite positioning. It is recommended that 10 m be the maximum allowable positioning error on any Phase I OCS survey and that survey vessels be required to maintain steerage of ± 20 m from the location of pre-plotted survey lines. All positioning data should be logged on computer for later use in the automated mapping of survey results. The time interval between navigational fixes shall be short enough to allow maintenance of the recommended steerage when dead-reckoning between fixes.

Archaeological reports resulting from prehistoric surveys should include scale maps illustrating the positions of all suspicious side-scan sonar targets that might represent karst features, sea caves, or historic wreck sites, and all sub-bottom geologic features that may indicate the presence of prehistoric archaeological sites. It is recommended that MMS develop a set of standard symbols to be used in the production of such maps and that a digital copy of all such maps be required as a deliverable to MMS in a format compatible with MMS' inhouse GIS or CAD capabilities.

All original sub-bottom and side-scan charts should be reviewed by a qualified marine survey archaeologist who would then be responsible for writing an archaeological report summarizing the results of the survey. The archaeological report should include a detailed explanation of and recommendations regarding each potential prehistoric site setting. The results of each survey should be discussed in the context of adjacent and/or nearby survey results. It is recommended that industry curate all survey data (either the original paper instrument charts or a digital-format-copy compatible with MMS' inhouse GIS or CAD capabilities) including deck logs. All original instrument charts must be carefully annotated during the course of the survey in order to assist with their analysis.

All unexplainable side-scan sonar targets and all sensitive landforms should be avoided by bottom-disturbing activities or else subjected to Phase II and possibly Phase III investigations as described in Section 4.2 above. Additional seismic survey at a maximum line-spacing of 40 m would be appropriate in the immediate area of proposed bottom-disturbing activities in order to determine the most productive areas to concentrate sediment coring. Sediment cores should be collected to the maximum depth of proposed bottom-disturbing activities or to the level of the pre-Holocene surface, whichever is less.

In prehistoric predictive zones designated as having no Holocene sediment cover (a) or as being non-sensitive landforms (b), no archaeological survey is recommended. The normal geohazard survey requirements would apply, however; thus, a large quantity of sub-bottom and side-scan sonar survey data would be generated over such areas. It is recommended that MMS require submission of digital maps illustrating this data, prepared to the same level as described above for prehistoric archaeological surveys. This data should be reviewed by an MMS archaeologist or by a qualified marine survey archaeologist and used to update and refine the Holocene Sediment Isopach Maps, the Submerged Paleo-Landform Maps, the Prehistoric Site Predictive Zone Maps, and the Historic Site Predictive Zone Maps of Volume V.

5.2.2 *Historic*

Phase I archaeological survey for historic sites should include the use of a proton precession magnetometer, side-scan sonar, and a recording fathometer. Three levels of magnetometer survey are suggested below, depending upon the predictive zone designation of a particular lease block (see maps in Volume V). No archaeological survey is recommended for Zone 1; and a 100-percent survey coverage (for wooden- or composite-hulled vessels) is recommended for lease blocks located within predictive zones 4a, 4b, 5a, 5b, 6a, and 6b; a 25 percent sample survey is recommended for zones 2a, 2b, 3a and 3b. The same recommendations regarding positioning methods and accuracy as described above for prehistoric surveys should also apply to historic surveys. A description of the specific survey recommendations for each historic predictive zone is provided below.

Historic Site Predictive Zone 1: No archaeological survey is recommended for Historic Site Predictive Zone 1. As with the Prehistoric Site Predictive Zones designated as 1a-5a and 1b-5b, the normal geohazard survey requirements would apply, thus a large quantity of sub-bottom and side-scan sonar survey data would be generated over these areas. It is recommended that MMS require digital maps of this data, done to the same level as described above for prehistoric archaeological surveys. This data should be reviewed by an MMS archaeologist or by a qualified marine survey archaeologist and used to update and refine the Holocene Sediment Isopach Maps, the Submerged Paleo-Landform Maps, the Prehistoric Site Predictive Zone Maps, and the Historic Site Predictive Zone Maps of Volume V. No formal archaeological report would be required for Zone 1.

Historic Site Predictive Zones 3ab and 4ab: A line-spacing of 150 m is recommended for magnetometer surveys in these areas. This represents approximately a 25-percent sample survey. All other recommendations regarding the manner in which magnetometer surveys be conducted remain the same. Side-scan sonar should be required on every survey line and configured to provide 100-percent coverage and the same minimum resolution and maximum range as recommended above.

Historic Site Predictive Zones 4ab, 5ab and 6ab: Archaeological survey of lease blocks for historic sites should provide 100-percent coverage with a magnetometer. A 40-m line-spacing is recommended. The magnetometer sensor should be towed at a distance behind the survey vessel of at least two and one half times the length of the vessel and at a maximum height above the sea floor of 6 m. A vessel speed of 4 to 6 knots is recommended for the survey. The magnetometer should be set to cycle at 1-second intervals. Magnetic data should be recorded on paper strip charts at a scale of 100 gammas or less, with no smoothing or averaging applied to the data, and on computer disk as an ASCII file that can be later be merged with positioning data to produce a magnetic contour map of the data. The sensitivity of the magnetometer should be at least 1 gamma. Background noise levels in the magnetic data should not exceed ± 3 gammas.

All original magnetometer strip charts should be curated along with a digital copy of the corresponding ASCII computer file. It is recommended that MMS provide a means for industry to curate these materials with MMS, rather than with other curatorial facilities so that all OCS survey data will be centrally housed and readily available for reference.

Side-scan sonar should be deployed for historic site survey at a line-spacing not to exceed 160 m (every fifth survey line). Towfish depth and range should be adjusted to provide 100-percent coverage of the sea floor with at least a 20-percent overlap between lines and better than 1-m resolution of objects on the sea floor. Range should not, however, exceed 100 m. Automatic correction for slant range and vessel speed should be required.

Archaeological reports resulting from OCS historic site surveys should be written by a qualified marine survey archaeologist who has thoroughly reviewed all of the original survey data. The report should include a detailed explanation of the survey results. All magnetic anomalies exceeding ± 6 gammas and a 4-second duration should be considered a potential historic archaeological site. All such anomalies should be prioritized regarding their potential for being caused by an historic site. This prioritization should have a sound basis in comparative empirical data. While no such anomalies could be justifiably excluded from recommendations for further work, such recommendations should be structured according to the prioritization scheme proposed by the Principal Investigator. The results of each survey should also be discussed in the context of adjacent and/or nearby survey results, addressing such issues as the relative density and distribution of magnetic anomalies and side-scan targets within the survey area and survey area vicinity.

It is recommended that industry curate all survey data, including deck logs, with MMS, including a digital copy, compatible with MMS' inhouse GIS or CAD capabilities, and the original (or a copy) paper instrument charts. Archaeological reports resulting from historic surveys should include magnetic contour maps of the area surveyed, contoured using a 5-gamma contour interval, and scale maps illustrating the positions of all side-scan sonar targets that might represent historic wreck sites. It is recommended that MMS develop a set of standard symbols to be used in the production of such maps and that a digital copy of all such maps be required as a deliverable to MMS in a format compatible with MMS' inhouse GIS or CAD capabilities.

All unexplainable magnetic anomalies and side-scan sonar targets should be avoided by bottom-disturbing activities or else subjected to Phase II and possibly Phase III investigations as described in Section 4.2 above. Ground-truthing on the OCS should be conducted as described above in Section 4.2. This would generally require the use of remotely operated vehicles with submersible cameras, since most of the Pacific Region OCS is beyond the normal safe depth of archaeological diver investigations. Whenever possible, however, it is recommended that divers be utilized for visual or tactile assessment of anomaly sources.

6.0 SUMMARY

In May 1989, the Pacific OCS Region of MMS contracted with EH&A of Austin, Texas, to conduct a study of the OCS between Morro Bay, California and the Canadian Border. This report is the last in a series of similar baseline reports which evaluate the archaeological potential of the OCS. The results of this study will be used in evaluating exploration, development and transportation plans for mineral development activities. The identification of areas on the OCS in which prehistoric and historic archaeological sites are likely to be preserved will assist MMS in determining remote-sensing survey requirements that will apply to specific portions of the study area. Several disciplines contributed to this study including: geology, prehistory and maritime history. The techniques of marine archaeology apply to both the prehistoric and historic aspects of this study.

Late Pleistocene and Holocene geology of the continental shelf were integral to this study. The primary geologic objectives were to characterize the OCS paleogeography at the end of the Pleistocene, when sea level was at its most recent low stand approximately 18,000 B.P., and to postulate the effects of subsequent sea level rise on landforms likely to contain prehistoric habitation sites.

Geologic data pertaining to the Pleistocene/Holocene transition is sparse for the study area, especially regarding Holocene sediment cover. The Pacific OCS is significantly narrower than the world average and over much of its area has a relatively gently sloping surface. At the end of the Pleistocene, the OCS (then a coastal plain) was apparently characterized by generally flat level terrain. Prior to about 10,000 B.P., coastal streams would have flowed along low gradient meander belts and probably would have carried high sediment loads. The combination of a low gradient coastal plain and an abundance of sand suggests the possibility that much of the northern study area coast may have been characterized by an energy-dissipating barrier island system prior to 10,000 B.P. The Texas Gulf coast may be an appropriate modern analog. The OCS off of California prior to 10,000 B.P. may have resembled the coast of southern Florida (except for the absence of karst topography off of California). By 10,000 B.P. the coast had migrated significantly eastward and was approaching the position of the modern coastline where the slope of the OCS is steeper. Wave energy would have been more severe and erosion more active as the wave ramp became steeper. The coastline position has changed relatively little in the past 7,500 years. By 3,000-5,000 B.P., sea level approximated that of today.

The most likely locations in the study area for the occurrence and preservation of submerged prehistoric sites are submerged estuaries, paleoembayments, lagoons, submerged river valley systems, and on the lee side of islands and headlands. Sites located along unprotected coastlines and in areas now lacking Holocene sediment cover are least likely to have survived wave erosion during inundation. Sites that were buried by sedimentation prior to inundation have the greatest chance for preservation in all environments. No submerged sites have been located in the study area; however, the potential is good for their occurrence and preservation under the proper circumstances.

Submerged landforms that are most likely to contain preserved prehistoric sites have been mapped in Volume V. The approximate locations of numerous submerged meander belts was inferred from the positions of modern river mouths and submarine canyons on the continental slope. These meander belts are also the most likely locations for drowned estuaries. Drowned islands and headlands were identified from modern bathymetric charts.

Approximately 3,850 shipwrecks have been historically documented for the study area. It is estimated that between 80 and 90 percent of these occurred in less than 10 m of water, in what has been referred to here as the nearshore zone. Harbor entrances, inner harbor waters, and

the nearshore zone are the most likely areas for the occurrence of shipwrecks. Mineral development activities associated with pipeline and port facility construction could affect wrecks in the nearshore zone. The balance of documented wrecks occurred offshore. Offshore wrecks are most likely to be impacted by OCS mineral exploration and development. The most likely locations for offshore wrecks are harbor approaches and high traffic sealanes.

A high correlation exists between severe weather and the occurrence of shipwrecks. Over 50 percent of all marine casualties in the study area were weather-related. The most significant weather conditions affecting vessel losses are high winds/heavy seas and fog, thus average wind speed and the frequency of low visibility due to fog were incorporated into the historic site predictive model.

Marine CRM requirements for compliance with Section 106 of the National Historic Preservation Act are presently lagging far behind the requirements for archaeology in terrestrial settings. This discrepancy seems to be based upon misperceptions regarding both the benefits and the relative cost of marine archaeology. Survey requirements, especially line-spacing, should be more stringent. A heavy emphasis should be placed on regional mapping of marine survey results so future survey results can be analyzed in the context of surrounding areas. Such a program would improve the quality both of data interpretations and of survey reports and would allow refinement of the archaeological site predictive models formulated for this study. Incorporation of such ideas into MMS' archaeological requirements could greatly increase the level of our knowledge regarding archaeological sites on the OCS while resulting in a significant cost savings to industry.

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